CONTRACT NO. 95-339
FINAL REPORT
DECEMBER 1998

Measuring Concentrations of Selected Air Pollutants Inside California Vehicles

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

MEASURING CONCENTRATIONS OF SELECTED AIR POLLUTANTS INSIDE CALIFORNIA VEHICLES

Final Report, ARB Contract No. 95-339

supported by
ARB Contract 95-339
and AQMD Contract 98055

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Acknowledgments

This project integrated the technical skills and personnel from a prime contractor, Research Triangle Institute (RTI), and three subcontractors, Sierra Research, Inc. (SR), Aerosol Dynamics, Inc.(AD), and Desert Research Institute (DRI). SR provided the mobile sampling platform used in all commutes, on-board instrumentation to measure and record traffic conditions, drivers and a navigator (primary vehicle only) for all vehicles, and rental vehicles. SR also selected the commuting routes used for each phase of the study. AD provided the characterization of "real" California aerosol, calibration of the optical particle counter for these aerosols, and the (leased) Aethalometer for monitoring black carbon. AD also provided aerosol monitoring consulting, and assisted in the initial installations of the particle counter and Aethalometer. DRI provided consulting on particle metals' analyses, and conducted the XRF metals' analyses (Main Study only). RTI provided all other equipment and technical services associated with both the Pilot and Main Studies, including the overall study design and project direction, field project direction, field operations technical staff, ICP/MS metals' analyses (Pilot Study only), automated data collection, analyses and interpretations, quality assurance summaries, and reporting. Staff from ARB assisted in the field operations by providing local logistical coordination, and collecting samples and data from the ambient monitoring sites. SCAQMD provided logistical support in Los Angeles. Specific individuals contributing to this project included:

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Sierra Research - Frank DiGenova (subcontract direction and field support), John Lee (traffic data collection, driving, navigation), Lori Williams (driving), Dwight Mitchell (driving), Josh Willter (driving), and Rob Hughes (driving)

Aerosol Dynamics - Susanne Hering (subcontract direction, aerosol measurement consulting, and field support), Mark Stolzenburg (aerosol characterization, particle counter calibration, field support), and Nathan Kreisberg (aerosol characterization, particle counter calibration, aerosol modeling).

Desert Research Institute - John Watson (metals' analysis consulting), Cliff Frazier and Barbara Hinsvark (XRF analyses - Main Study only), and Charles Whitaker (coordination)

ARB - Steve Hui (overall project direction, logistical support in Sacramento collection of ambient monitoring data, sampler assistance), Peggy Jenkins (project direction, sampler assistance), Steve Brisby (sampler assistance), and Dorothy Shimer (sampler assistance)

SCAQMD - Shankar Prasad (technical support in Los Angeles)

This report was submitted in fulfillment of ARB contract 95-339 and (partial sponsorship) SCAQMD contract 98055, "Measuring Concentrations of Selected Air Pollutants Inside California Vehicles", by the Research Triangle Institute and its subcontractors (Sierra Research, Aerosol Dynamics, Desert Research Institute), under the partial sponsorship of the California Air Resources Board. Field work was completed as of 10/10/97.

TABLE OF CONTENTS

List of Tables

List of Figures

ABSTRACT

Researchers measured pollutant concentrations inside vehicles on California roadways during 32 driving trips in the cities of Los Angeles and Sacramento. For most of the pollutants, two-hour integrated samples were collected concurrently inside the vehicle, just outside the vehicle, along the roadway where the vehicle traveled, and at ambient monitoring sites. Pollutants measured included PM_{10} and $PM_{2.5}$, metals, and 13 organic chemicals including benzene, MTBE, and formaldehyde. In addition, the researchers obtained continuous measurements of fine particle counts, carbon monoxide (CO), and black carbon. The driving scenarios were designed to evaluate the association between in-vehicle pollutant levels and factors such as the carpool lane, traffic congestion, vehicle type, roadway type, time of day, and ventilation setting.

In-vehicle pollutant levels were generally higher in Los Angeles than Sacramento. In Los Angeles, the average in-vehicle concentrations of benzene, MTBE, and formaldehyde ranged from 10-22 $\mu g/m^3$, 20-90 $\mu g/m^3$, and 0-22 $\mu g/m^3$, respectively. In Sacramento, the average in-vehicle concentrations for benzene, MTBE, and formaldehyde ranged from 3-15 $\mu g/m^3$, 3-36 $\mu g/m^3$, and 5-14 $\mu g/m^3$, respectively. The ranges of mean PM_{10} and $PM_{2.5}$ in-vehicle levels in Los Angeles were 35-105 $\mu g/m^3$ and 29-107 $\mu g/m^3$, respectively. The ranges of mean PM_{10} and $PM_{2.5}$ in-vehicle levels in Sacramento were 20-40 $\mu g/m^3$ and 6-22 $\mu g/m^3$, respectively.

In general, VOC and CO levels inside or just outside the vehicles were higher than those measured at the roadside stations or the ambient air stations. However, in-vehicle levels of $PM_{2.5}$ were consistently lower than $PM_{2.5}$ levels just outside the vehicles and, in many cases, also lower than roadside levels. Nonetheless, $PM_{2.5}$ levels inside or just outside the vehicles were usually higher than levels measured at the nearest ambient site. Except for sulfur, metal concentrations were generally low or below detection limits. Pollutant levels measured inside vehicles traveling in a carpool lane were significantly lower than those in the right-hand, slower lanes. Under the study conditions, factors such as vehicle type and ventilation settings were shown to have little effect on the in-vehicle pollutant levels. Other factors, such as roadway type, freeway congestion level, and time-of-day were shown to have some influence on the in-vehicle pollutant levels. Elevated levels of both fine particles and black carbon were measured inside the test vehicle when it followed diesel-powered vehicles.

This study provided the data needed to characterize in-transit exposures to air pollutants for California drivers. It also demonstrated a number of *in-situ* monitoring techniques in moving vehicles and provided findings that shed new light on particle exposure assessments and research needs.

EXECUTIVE SUMMARY

BACKGROUND - In order to evaluate Californians' total exposure to air pollutants, it is necessary to account for the important microenvironments where people spend the majority of their time. Pollutant concentration data are very limited for many microenvironments, including vehicle passenger compartments. This study was conducted to characterize the concentration levels of selected pollutants inside commuting vehicles in the Sacramento and Los Angeles areas in California. The researchers collected samples integrated over two hours for $PM_{2.5}$ and PM_{10} mass, a number of particle-associated elements, and 13 VOC's, including methyl-tertiary-butyl-ether (MTBE), benzene and formaldehyde. In addition, continuous measurements were made for carbon monoxide (CO), black carbon, and particle count for different particle sizes, ranging from 0.15 to 2.5 μm. This is the first study to measure $PM_{2.5}$ and PM_{10} concentrations inside vehicles. The use of continuous samplers for measuring both particle count and black carbon, while commuting, is also ground-breaking and innovative.

The research was "range-finding" for a wide variety of commuter exposure scenarios, rather than an in-depth evaluation of a few situations. Study objectives included measuring the concentrations of selected pollutants inside and outside the vehicles to evaluate the influences of: 1) freeway conditions (rush versus non-rush), 2) roadway types (freeway, arterial and rural), 3) four vehicle types (2 sedans, a sport-utility vehicle and a California school bus), 4) two driver-adjusted vent settings, 5) the time of day (AM versus PM), and 6) the relationships among pollutant concentrations inside and outside the vehicles compared to roadside and the nearest ambient fixed site monitoring location. The results of this study can be used to define methodologies for assessing both commute-average and real-time in-vehicle concentrations, improve the estimates of current Californians' in-vehicle pollutant exposures, assess the relative contributions of in-vehicle concentrations to total air exposure, suggest actions that drivers and passengers could take to reduce their in-vehicle exposures to air pollutants, and determine the need and feasibility of future in-vehicle studies.

METHODS – In September and October of 1997, researchers collected a number of 2-hour pollutant concentration measurements inside vehicles during 13 "commutes" in Sacramento and 16 in Los Angeles. Similar measurements were made simultaneously outside the vehicles, along the roadways, and at the nearest ambient air monitoring stations. A variety of scenarios were studied based on variables such as roadway type, traffic congestion, ventilation setting, and vehicle type. Two runs, one in the morning and one in the afternoon, were typically conducted for each scenario. The study also included several in-vehicle special driving scenarios: 1) a California school bus following a student route in Sacramento, 2) comparison of a sedan traveling in an LA carpool lane versus one traveling in a congested right hand lane, and 3) a sedan encountering situations that would maximize the in-vehicle pollutant concentration levels.

A driving protocol was followed that highlighted trailing behind heavy duty diesel (HDD) vehicles and diesel city buses when possible, to estimate their contributions to the measured pollutants. This focus on trailing specific polluting vehicles provided potentially "high end" estimates of the in-vehicle concentrations for particle count and black carbon.

Two-hour integrated samples for $PM_{2.5}$ and PM_{10} were collected by MSP personal impactors on Teflon filters. The filters were weighed for particle mass and later analyzed for elemental concentrations by XRF. Except for formaldehyde, all the VOC's were collected by

SUMMA evacuated canisters and were analyzed by GC/MS. Formaldehyde was collected by DNPH cartridges for subsequent HPLC analysis. Continuous CO monitoring was measured by Draeger monitors. Real-time black carbon concentrations were measured with an Aethalometer, while particle counts were measured with a LAS-X optical particle counter. The continuous data were reduced to both 1 minute and 120 minute "commute" averages.

RESULTS – Pollutant levels measured inside vehicles traveling in a carpool lane were much lower than those in the right-hand, slower lane. As expected, in-vehicle pollutant concentrations obtained from freeway rush drives were higher than those from freeway non-rush drives. Under the study conditions, factors such as vehicle type, and vehicle ventilation settings were shown to have little effect on the in-vehicle pollutant levels. Other factors such as roadway type, and time-of-day appeared to have some indirect influence on the in-vehicle pollutant levels. Elevated levels of both fine particles and black carbon were measured inside the test vehicle when it followed diesel-powered vehicles. Other pollutant measurement highlights included: (a) most pollutant levels, especially the VOC's, were elevated inside and outside the vehicles, relative to either the roadside or ambient station concentrations, (b) most pollutant levels were extremely low at the rural site near Sacramento, relative to any of the arterial or freeway locations, (c) most pollutant levels were somewhat higher in Los Angeles than in Sacramento, (d) particle concentrations were typically significantly higher outside the vehicles than inside, presumably due to losses in the vehicle ventilation systems (and other factors) - while significant differences were not observed between inside and outside levels of gas phase pollutants for the same vehicle, (e) in-vehicle pollutant concentrations for some individual commutes were substantially influenced by the tailpipe emissions from single polluting "target" lead vehicles, and (f) total in-vehicle LAS-X particle count/cm^3 (0.15 to 2.5 μm) was a fair predictor of integrated $PM_{2.5}$ mass concentration.

The mean ranges of selected in-vehicle pollutant concentrations (both integrated and continuous measures) by location are summarized as follows:

Pollutant	Sacramento In-Vehicle*	Sacramento Ambient*	Los Angeles In-Vehicle*	Los Angeles Ambient*
MTBE, μg/m^3	3 to 36	2 to 7	20 to 90	10 to 26
Benzene, μg/m^3	3 to 15	1 to 3	10 to 22	3 to 7
Toluene, μg/m^3	7 to 46	4 to 8	22 to 54	10 to 40
$PM_{2.5}$, μg/m^3	6 to 22	6 to 11	29 to 107	32 to 64
PM_{10}, μg/m^3	6 to 22	20 to 30	29 to 107	54 to 103
Formaldehyde, μg/m^3	5 to 14	2 to 4	<MQL to 22	<7 to 19
CO, ppm	<MQL to 3	<MQL	3 to 6	<MQL
Black Carbon, μg/m^3	<MQL to 10	na	3 to 40	na
LAS-X, tot. particles/cm^3	10 to 1,100	na	2,200 to 4,600	na

Table Notes: *means of 2 to 4 commutes; <MQL – below quantification limit; na – not avail.

The methodology highlights for this study included demonstrating that: (a) in-vehicle VOC's, $PM_{2.5}$ and PM_{10} gravimetric mass concentrations could be successfully determined, even though the samples were integrated over very short 2 hour periods, (b) real-time black carbon monitoring was feasible inside A commuting vehicle, (c) useable, integrated 2-hr in-vehicle

samples for NO_2 and PAH's could not be collected , (d) the relatively low levels of CO currently found in commuting California vehicles, posed a substantial measurement problem for low-cost monitors with elevated MQL's, and (e) continuous monitoring of in-vehicle particle count (<2.5 μm) and black carbon concentrations could be readily be associated with emission of diesel-powered and poorly tuned gasoline-powered vehicles just ahead of the study vehicles.

CONCLUSIONS – This study provided, for the first time, a variety of in-vehicle pollutant concentration levels for California vehicles. The study design also provided an indication of the potential influence of specific tested factors on in-vehicle concentration levels for selected pollutants. However, because the number of drives designed for testing a specific factor was typically small, some of the results should be confirmed by future studies with larger sample sizes and enhanced study designs. In addition, some of the possible confounding variables that may affect the results include: (a) the experimental driving protocol (trailing specific polluting target vehicles), (b) the high air exchange rate between the cabin and outside air during all the runs, (c) the local meteorology (e.g. wind speed), (d) the potential influence of emissions from the lead vehicle, and (e) the distance between the test vehicle and the lead vehicle.

Other significant conclusions were: (a) the influence of individual polluting vehicles immediately in front of the test vehicles was substantial on in-vehicle levels, even for short periods, occasionally accounting for 30 to 50 % of the total in-vehicle commute concentrations, (b) the inside-to-outside ratio of particle mass for particles <2.5 μm ranged from 0.6 to 0.8, (c) concentrations inside a California school bus were very low in Sacramento, reflecting the generally low concentrations in the residential neighborhood, (d) LA non-carpool lane commutes generally have substantially higher in-vehicle pollutant concentrations by 30 to 60 %, as compared to the carpool lanes (the use of which additionally reduced total commute air exposures by reducing total commuting time), (e) maximum concentration situations during commutes (e.g. closely trailing a diesel city bus in a downtown street canyon) could readily double the short-term in-vehicle concentrations for selected pollutants, and (f) roadside pollutant measurements were low by a factor of at least two for predicting in-vehicle levels for many commuting scenarios, but provided significantly better indications of in-vehicle pollutant concentrations than did ambient sites, which were often low by a factor of three or more (especially for VOC's).

Recommendations for future work include: a) conducting a more in-depth analysis of the extensive data bases developed in this study – especially for the real-time measurements, b) obtaining more representative commute data, across different locations, seasons, traffic conditions, etc., c) improving the sampling equipment for real-time measurements of particles, d) developing suitable sampling methodologies for collecting measureable, short-term samples of NO_2 and PAH's, e) further quantifying the advantages of carpool commuting relative to reducing pollutant exposures, f) further evaluating the relative importance of single lead vehicles on in-vehicle exposures, especially when following heavy duty diesel vehicles and older, gasoline powered vehicles, and g) developing relationships between trailing distance and in-vehicle concentrations. The robust data base developed to meet study objectives undoubtedly contains a wealth of additional information that can be related to in-vehicle passenger exposures. Although the limited number of commutes conducted for each scenario cannot be construed as completely

representative, the quality and consistency of the data strongly suggest that the proposed focused studies be considered.

PREFACE

This report summarizes the field monitoring and the data collected from a September/October, 1997 Main Study conducted at two locations to assess in-vehicle air concentrations in California vehicles for selected pollutants and driving scenarios. A Pilot Study report (attached as Appendix A) was previously prepared by RTI and submitted to ARB that summarized the findings of an earlier February, 1997 Sacramento study that was used to finalize methodologies, characterize their performance, and report expected concentration levels. Details on the performance of the methodologies from the pilot effort are not included in the main body of this report. The current report summarizes the Main Study findings for both Sacramento and Los Angeles field operations, involving a total of 29 in-vehicle commutes (13 in Sacramento, 16 in Los Angeles). The Main Study was primarily funded by ARB, with supplemental support provided by SCAQMD to provide more comprehensive sample and data analyses for the Los Angeles commutes. The latter additional work in LA included additional sampling days, more robust formaldehyde sampling, and detailed video-assisted associations of the continuous pollutant concentrations with the lead vehicle type. A co-project officer (Linda Sheldon) is currently employed with the U. S. Environmental Protection Agency (Research Triangle Park, NC).

1.0 INTRODUCTION

1.1 BACKGROUND:

The California Health and Safety Code (HSC) Section 39660.5 requires the California Air Resource Board (ARB) to assess human exposure to toxic pollutants. The ARB is also required to identify the relative contribution of indoor concentrations to total exposure, taking into account both ambient and indoor air environments. In order to assess a population's pollutant exposure, it is necessary to account for the important microenvironments where people spend their time. This requires information on how much time people spend in specific microenvironments and the corresponding pollutant air concentration in those microenvironments. Although the ARB has representative data on Californian's activity patterns (Wiley et al., 1991a, 1991b), very little pollutant concentration data are available for many microenvironments including vehicle passenger compartments.

A field measurement study was proposed by the ARB that would substantially enhance the current knowledge based for pollutants in vehicular settings. The experimental focus in the request for proposal could be more appropriately characterized as "range-finding" for a wide variety of commuter exposure scenarios, rather than an in-depth evaluation of a few situations. The results of this study would be used by ARB to determine the need for, and feasibility of, additional in-vehicle pollutant measurements in more focused future studies. The results of this project could also be used by the ARB to improve estimates of current Californian in-vehicle exposures to selected pollutants, and to assess the relative contribution of in-vehicle exposure to total air exposure for these pollutants. In addition, the results could be used to identify actions that driver and passengers may take to reduce their in-vehicle exposures to air pollutants.

An ARB contract (95-339) was issued to the Research Triangle Institute (RTI) in late 1996 to characterize the concentration levels of selected pollutants associated with an inter-related matrix of commuting scenarios, vehicle types, and ventilation settings. The driving scenarios were those most likely to produce a full range of probable in-vehicle concentrations, with emphasis given to commuting scenarios likely to result in elevated in-vehicle exposures. Measurements were to be obtained inside passenger vehicles, immediately outside the vehicles, along the roadway where the vehicles travel, and at ambient monitoring sites. The field data would be collected at two locations in California, Sacramento and Los Angeles, during a seasonal period likely to produce the highest in-vehicle exposures. The ARB contract was supplemented by the South Coast Air Quality Management District (SCAQMD) in late 1997, prior to the Main Study testing in Los Angeles. The SCAQMD requested that additional in-vehicle formaldehyde measurements be made in Los Angeles, additional commutes be added, and additional data analyses be conducted to provide more thorough characterization of the five highest particle concentration commutes in Los Angeles.

The workplan proposed by RTI[1], incorporated all of the requirements of the ARB proposal, and suggested the inclusion of continuous optical particle counting and black carbon concentration measurements. These continuous measures would serve as indices of shorter term particle exposures, and could provide links to possible contributing sources, including diesel vehicles. The potential methodological problems posed by sampling in a moving vehicle over relatively short sampling times (2 hours), strongly suggested that the bulk of the sampling be preceded by a Pilot Study. This pilot effort was conducted in February, 1997, in Sacramento, CA to fine tune the sampling procedures and approximate the concentration levels expected to be encountered. The

[1] The initial workplan to ARB initiated the project, while a supplemental effort with SCAQMD extended the scope of sampling and analysis in Los Angeles

analyses of samples and data from this study permitted the sampling methods to be optimized to maximize the quality of the data, as well as the data capture rate. The Main Study was initiated in late September, 1997, with 13 2-hr commutes over 7 sampling days in Sacramento. After a brief period to relocate the staff and equipment, the field study was resumed in Los Angeles, CA for an additional 16 2-hr commutes over 9 sampling days.

1.2 MAIN STUDY OBJECTIVES

Table 1-1 lists the pollutants selected by ARB for monitoring in the Main Study, as well as the elements inherent in the study design. A strong emphasis was placed on obtaining reliable concentration data for particles and methyl *t*-butyl ether (MTBE), as well as $PM_{2.5}$, PM_{10} , particle elements, VOC's, CO, and black carbon. Gravimetric particle concentration for only 2 hour periods are extremely difficult to accomplish, at the low flowrates required to minimize the influence of the sampler flowrates on the vehicle air exchange rates. The optimization testing required to make these particle measurements is described in the Pilot Study report (Appendix A). Measurements were obtained inside passenger vehicles, immediately outside the vehicles, along the roadway at two locations adjacent to where the vehicles traveled, and at a fixed ambient monitoring site in Sacramento and in Los Angeles. Measurements were obtained during driving scenarios that were likely to produce the full range of probable in-vehicle concentrations, but emphasis is given to scenarios likely to result in high in-vehicle exposures. Table 1-1 also lists the other data that may be collected in addition to the chemical measurements and the required driving scenarios.

A list of research design objectives were formulated taking into account ARB's program goals as well as the important factors that can affect in-vehicle pollutant concentrations. These research objectives were finalized based on inputs from the ARB, SCAQMD and results of the pilot testing. The finalized research objectives were used to define the data collection requirements and the data analysis approach for the Main Study. The design objectives incorporated into this program are given in Table 1-2 organized by influencing factors.

TABLE 1-1. Main Study Design Elements

Pollutants:	PM_{10} Particle Mass $PM_{2.5}$ Particle Mass Particle Elements for $PM_{2.5}$ and PM_{10}: Cadmium (Cd), Chromium (Cr), Lead (Pb), Manganese (Mn), Nickel (Ni), Sulfur (S), plus 34 other supporting elements VOC's: isobutylene, 1,3-butadiene, acetonitrile, dichloromethane [DCM], methyl-tertiary-butyl-ether [MTBE], ethyl-tertiary-butyl ether [ETBE], benzene, toluene, ethylbenzene, o-xylene, m,p-xylene, and, trichloro-fluoro-methane [TCFM]) CO Formaldehyde Total Particle Count/cm3 in 12 sizes, 0.15 μm - 2.5 μm Black (elemental soot) Carbon
Other Measurements:	Vehicular Characterization: vehicle speed, traffic density [Level of Congestion], vehicle spacing distance, commute video record Meteorology: ARB provided data: temperature, relative humidity, wind speed, and wind direction
Metropolitan Areas:	Sacramento, CA, Los Angeles, CA
Vehicle Types:	Sedans: 1991 Chev. Caprice, 1997 Ford Taurus Sport Utility Vehicle: 1997 Ford Explorer California diesel-powered school bus
Vehicle Ventilation Settings:	High: windows closed, outside vent open, medium fan speed Low: windows closed, outside vent closed, medium fan speed Note: window-open vent settings in the Pilot Study were not used in the Main Study
Driving Scenarios (roadway type and level of congestion:	Freeway Rush (FR) Freeway Rush Carpool (FRC) Freeway Non Rush (FNR) Arterial Rush (AR) Arterial Non-Rush (ANR) School Bus (SB) Maximum Concentration (MC)
Driving Periods (time of day):	AM, PM

TABLE 1-2. Specific Research Design Objectives Grouped By Influencing Factor Type For the Main Studies

Data Base Development

B1. Measure the concentrations of selected pollutants inside and outside California vehicles during commutes consisting of selected scenarios that define an expected range of concentrations from "best" to "worst" case.

Driver Selected Ventilation Options

C1. Evaluate the differences between inside and outside vehicle contaminant concentrations and their relationships to 2 driver (or passenger) adjusted ventilation control settings, to provide two levels of outside air exchange rates (high and low air exchange rates, AERs).

Vehicle Factors

D1. Evaluate the influence of four vehicle types (2 different sedans, a sport-utility vehicle (SUV), and a California school bus) on occupant exposure levels.

Roadway Factors

E1. Evaluate the influence of 3 roadway types (freeway, arterial, and rural) on in-vehicle concentrations.

E2. Evaluate the influence of freeway lane positions (carpool compared to normal lane) on in-vehicle concentrations.

E3. Evaluate the influence of "worst-case" roadway settings that may produce the maximum in-vehicle concentrations.

Traffic Factors

F1. Evaluate the influence of 2 freeway conditions (Rush hour and Non-Rush hour) on in-vehicle concentrations.

F2. Evaluate the influence of the average traffic speed, traffic density (Level of Congestion by visual observation), vehicle separation distance on in-vehicle concentrations.

Meteorological Factors

G1. Evaluate the influences of meteorological variables (wind speed, wind direction, temperature, relative humidity) on in-vehicle concentrations.

Temporal Factors

H1. Evaluate the influence of AM versus PM commutes on in-vehicle concentrations in Sacramento and Los Angeles

H2. Evaluate the variability of inside and outside concentrations of CO, particle count, and black carbon over the period of 120 minute commutes

Spatial Factors

I1. Evaluate the relative relationships of selected pollutant concentrations inside vehicles, outside vehicles, at contemporaneous roadside locations, and at fixed-site ambient monitoring locations.

1.3 Main Study Design

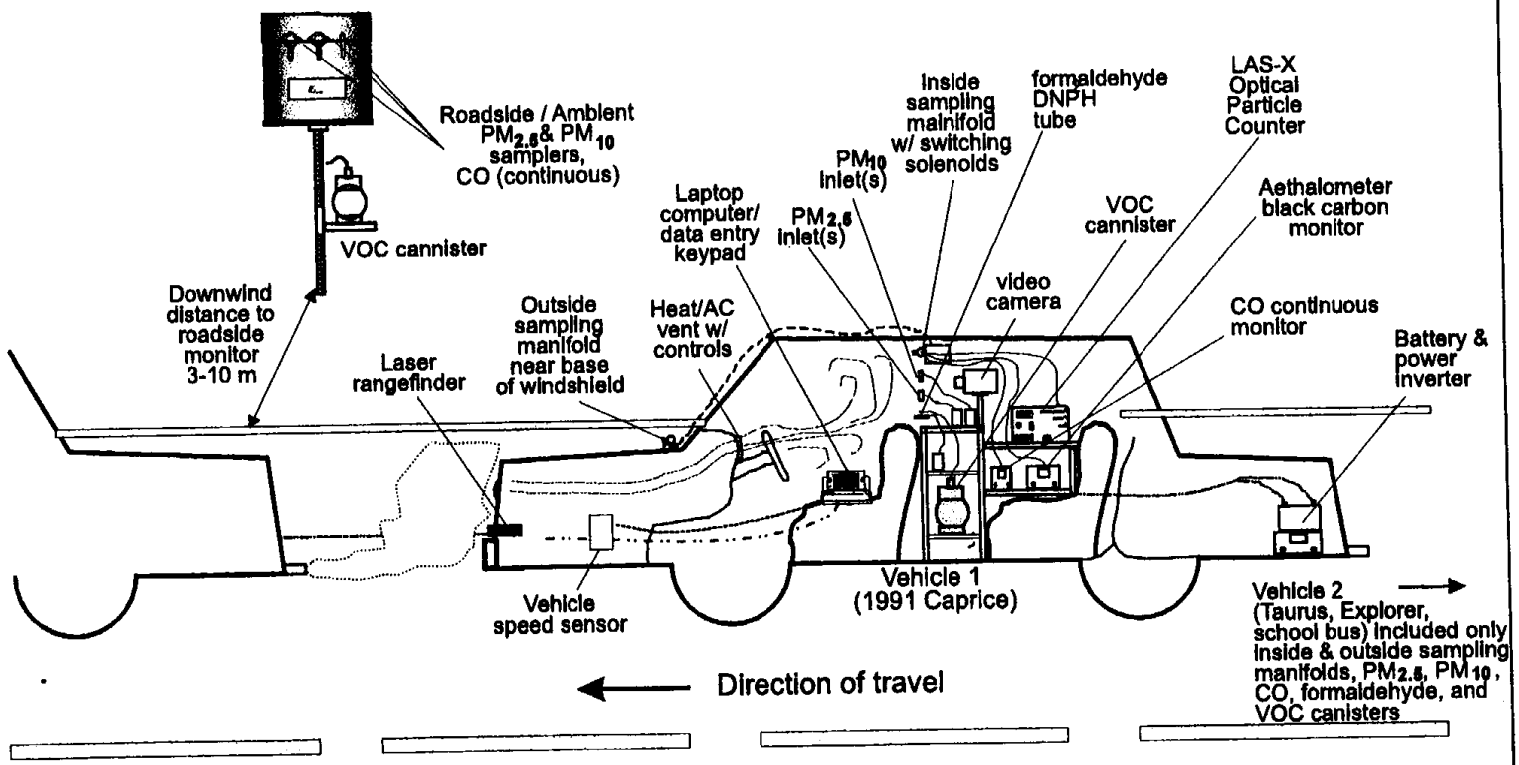
The overall in-vehicle program was conducted in two phases. Phase 1 was a Pilot Study and Phase 2 was the Main Study. The Pilot Study was designed to address four objectives: (1) evaluation of the monitoring methods proposed for the Main Study, (2) collection of limited pollutant monitoring data in Sacramento for the pollutants and other parameters proposed for the Main Study, (3) collection of real-time particle monitoring data in Sacramento for particle count and black carbon, plus a limited set of measurements for PAH's, and, (4) final definition of the research objectives for the Main Study. A brief summary of the findings from the separate Pilot Study report are given in Section 1.4.

The Main Study focused on pollutant and supplemental data collection during 2 hour in-vehicle commutes in Sacramento and Los Angeles. The primary vehicle was a heavily-instrumented sedan (1991 Chevrolet Caprice) provided by Sierra Research. As shown in Figure 1-1, the vehicle had a full complement of integrated and continuous pollutant measurement devices, plus traffic characterization equipment including a video camera. Secondary vehicles were selected to trail this "lead" vehicle during each commute, and consisted of a 1997 Ford Taurus sedan, a 1997 Ford Explorer (SUV), and a 30 foot diesel California school bus. The sedans and the SUV were gasoline-fueled, California vehicles. Even though the "typical" commute times in Sacramento and Los Angeles are for somewhat shorter periods, a 120 min (2 hour) driving time was selected, based primarily on the minimum time required to collect integrated samples (especially $PM_{2.5}$ particles) in sufficient quantities for subsequent analyses. This extended commute period was also expected to "smooth" the contribution of single high concentration events.

The 120 minute "commute" period was intended to allow the measurement of concentration levels representing typical driving scenarios. In some cases the commute route required "back-tracking" along the same route until 120 minutes had elapsed. In the case of more circular routes, the 120 minute drives continued in the same direction for the duration. In each run, the "commute" attempted (as much as possible) to drive in the direction of the predominant traffic flow. Note that the 29 different driving runs conducted during this study are referred to as "commutes", even though they are actually simulations.

While the number of commutes in the Main Study made it impossible to emulate all potential commuting scenarios, the ones selected represented a cross-section of freeway and arterial commute situations most likely to be encountered. The specific routes selected represented typical freeway and arterial settings in the two metropolitan areas, with an emphasis placed on routes that are typically heavily traveled. Selection of morning and evening Rush Hour commute periods (6:30 to 8:30 AM, and 4:30 to 6:30 PM) were compared against morning and afternoon Non-Rush Hour periods (8:30 to 10:30 AM, and 2:30 to 4:30 PM). Only a limited number of vehicle types could be evaluated concurrently in each commute, with the selection of specific vehicles to (a) represent commonly used vehicles in southern California, and (b) to simplify the acquisition of vehicles to test by using rental vehicles. Little information existed on the expected range of Air Exchange Rates by California vehicle type that might have assisted in the selection process. Measurement of the concentrations immediately outside each tested vehicle, provided the concentration levels that would be encountered, regardless of vehicle type or vent setting.

Figure 1-1. Inside, Outside and Roadside Vehicular Measurements for ARB Main Study



Commute-average (120 min) concentration measurements were made for number of pollutants, including: $PM_{2.5}$ particle mass, PM_{10} particle mass, a suite of volatile organic compounds (VOC's), and formaldehyde. The $PM_{2.5}$ and PM_{10} filters were also analyzed for a suite of metals. The integrated samples were collected immediately behind the back seat to represent the inside concentration in each vehicle. The outside concentrations were determined from a sample drawn through a sample line with an intake on the hood of each vehicle, immediately in front of the windshield. Several continuous pollutant measurements were also made (primarily in the fully-instrumented Vehicle 1 (1991 Chevrolet Caprice) and reduced to 120 one minute averages for each commute, including: carbon monoxide (all vehicles) , total particle count (Vehicle 1), and particle black carbon (Vehicle 1). A more detailed description of the pollutant measurements made and the analytical methodologies are provided subsequently in Section 2.1.

Pollutant measurements were concurrently made at 2 roadside locations along the route for most commutes to estimate the value of proximal monitoring to the roadway as a possible estimator of in-vehicle concentrations. In order to relate the in-vehicle pollutant measurements to the background concentrations, a nearby ARB ambient background monitoring location was selected at which to collect concurrent pollutant concentration measurements. Vehicular characterization measurements included Air Exchange Rate (AER), vehicle speed, vehicle spacing (to the vehicle immediately in front of Vehicle 1, and the subjectively determined Level of Congestion. The AER for each vehicle was determined at fixed speeds to generally characterize the influence of the ventilation settings. Even though these AER's were not commute averaged, they provided relative indications of the ventilation rates between vehicle types.

Several special studies were conducted in order to provide at least limited information on specific in-vehicle scenarios. A single rural commute was conducted in Sacramento (a "rural" commute location could not readily be identified for Los Angeles) to provide a general background comparison of concentration levels in a non-urban setting with very limited traffic. A pair of school bus commutes was conducted in a Sacramento neighborhood setting to estimate typical concentration levels inside and outside of a diesel school bus following a actual bus commuting route. A pair of carpool lane commutes was conducted in Los Angeles to compare the concentrations in the carpool lane with those simultaneously present in the non-carpool lanes. A pair of maximum concentration commutes was conducted in Los Angeles, focusing on the situations most likely to maximize particle and VOC concentrations (e.g. closely following a smoking diesel bus, incorporating a gasoline re-fueling stop). While very limited in scope, these special tests, provided information on several commuting scenarios for which no data had been available.

1.4 PILOT STUDY SUMMARY

The Pilot Study final report (see Appendix A) evaluated all methodologies used in the Main Study and made recommendations for changes in selected hardware and measurement methods. The details of this report will not be repeated here, but some of the most salient changes included:

- upgrading of the in-vehicle power supply in Vehicle 1 to provide fail-safe power for the Aethalometer and LAS-X continuous monitors,
- increasing the flowrate of the PM_{10} samplers from 2.0 to 4.0 lpm to provide enough sample mass to gravimetrically analyze,

- retaining the LAS-X and Aethalometer for the Main Study because of the added data value,
- retaining 2 of the 4 roadside monitors in the Main Study,
- modifying the sealing system of the $PM_{2.5}$ particle samplers to assure leak tightness,
- evaluating the $PM_{2.5}$ inlets against EPA reference samplers to assure comparability,
- moving the outside sampling line inlet from the front of the grill back to the base of the windshield to more closely sample the air entering the vehicle vent systems,
- switching the elemental analysis method from the more expensive ICP/MS to the less sensitive XRF to analyze all filters, instead of a subset,
- conducting limited vehicular air exchange rate tests at other vehicle speeds to estimate their influence on ventilation,
- more carefully synchronizing clock times during the field sampling to assist in inter-relating the continuous monitoring data.

The pollutants measured in the Pilot Study differed somewhat from those measured in the Main Study, and are summarized in Tables 2-1A, 2-1B, and 2-1C. Elevated winds during the Pilot Study produced extremely low concentration levels near or below the detection limits for most pollutants. The Pilot Study final report is attached in Appendix A.

Table 1-3A. Summary Table of Measurements Comparing Six Freeway Commutes (Mean) with One Rural Commute

	Commute	Ambient	Out-Car Mean	In-Car Mean	In-Car Range	Roadside Mean	Roadside Range
VOC's (μg/m³)							
1,3-Butadiene	Freeway	0.53	2.63	2.57 (0.28)	1.4 - 3.1	1.24	0.83 - 1.63
	Rural	0.0	0.0	0.0 (0.0)		na	na
MTBE	Freeway	3.93	13.00	13.98 (9.03)	8.9 - 19.0	7.22	6.15 - 8.58
	Rural	1.0	1.4	1.6 (0.0)		na	na
ETBE	Freeway	0.0[3]	0.0	0.0	na	0.0	0.0
	Rural	0.0	0.0	0.0		na	na
Benzene	Freeway	na	na	na	1.7 - 4.6	na	na
	Rural	na	na	na		na	na
Toluene	Freeway	10.17	24.17	26.33 (29.83)	15 - 37	14.62	11.68 - 19.10
	Rural	3.2	4.6	5.8 (5.0)		na	na
m,p-Xylene	Freeway	4.38	15.00	16.83 (18.63)	10 - 21	7.67	5.68 - 9.83
	Rural	1.5	1.8	3.4 (3.3)		na	na
o-Xylene	Freeway	1.85	6.12	6.77 (6.47)	4.3 - 8.1	3.34	3.03 - 4.00
	Rural	0.8	0.9	1.5 (0.0)		na	na
Formaldehyde (μg/m³)	Freeway	na	na	9.5	4.3 - 11.0	na	na
	Rural	na	na	9.6		na	na
PM_{10} (μg/m³)	Freeway	43.0	na	63.5	33 - 84	65.8	54.3 - 78.6
	Rural	28.0	na	18.0		na	na
$PM_{2.5}$ (μg/m³)	Freeway	50.8	45.2 (49.0)	35.2 (44.6)	16 - 64	31.5	24.8 - 38.0
	Rural	31.0	13.0 (26.0)	24.0 (22.0)		na	na
Carbon (μg/m³)	Freeway	na	5.96	7.08		na	na
	Rural	na	na	1.3		na	na
CO (ppm)	Freeway	0.1, 0.1[4]	2.7, 2.4	2.2, 1.7		0.4, 0.4	0.2 - 0.9, 0.2 - 0.7
NO_2 (ppb)	Rural	0, 0	0, 0	0, 0		na	na
	Freeway	42.2, 38.0	61.2, 41.0	78.3, 63.5		25.3, 33.5	25.3 - 86.0, 17.5 - 51.8
	Rural	9.0, 5.0	1.0, 1.0	0.0, 29.0		na	na

See table notes following Table 1-3C

Table 1-3B. Summary Table of Measurements Comparing Six Freeway Commutes (Mean) with One Rural Commute (cont'd)

	Commute	Ambient	Out-Car Mean	In-Car Mean	In-Car Range	Roadside Mean	Roadside Range
PAH's (ng/m3)							
Benzo[b]fluoranthene	Freeway	0.2	0.5	0.2	na	0.5	na
	Rural	0.1	0.3	0.0	na	na	na
Benzo[k]fluoranthene	Freeway	0.1	0.1	0.1	na	0.1	na
	Rural	0.1	0.2	0.0	na	na	na
Benzo[e]pyrene	Freeway	0.1	0.3	0.2	na	0.3	na
	Rural	0.0	0.0	0.0	na	na	na
Benzo[a]pyrene	Freeway	0.1	0.3	0.3	na	0.2	na
	Rural	0.1	0.1	0.1	na	na	na
Indeno[1,2,3-	Freeway	0.2	0.4	0.5	na	0.3	na
	Rural	0.0	0.2	0.1	na	na	na
Benzo[ghi]perylene	Freeway	0.2	0.8	1.0	na	0.6	na
	Rural	0.0	0.2	0.0	na	na	na
$PM_{2.5}$ Metals (ng/m3)							
Cadmium (Cd)	Freeway	0.16	0.23	0.09 (0.12)	0.0 - 0.12	0.24	0.0 - 0.46
	Rural	0.0	na	na	na		
Chromium (Cr)	Freeway	103.7	108.0	76 (122)	2.7 - 109	104	76.5 - 114
	Rural	0.0	na	na	na		
Manganese (Mn)	Freeway	14.6	5.6	6.4 (6.1)	.25 - 6.8	2.1	0.2 - 4.0
	Rural	0.0	na	na	na		
Nickel (Ni)	Freeway	0.0	0.0	25 (0.0)	na	10.3	0.0 - 29.0
	Rural	0.0	na	na	na		
Lead (Pb)	Freeway	9.2	7.6	15.7 (7.8)	11 - 24	5.3	3.1 - 9.0
	Rural	0.0	na	na	na		
Sulfur (S)	Freeway	293.3	356.0	342 (274)	231 - 575	299	166 - 392
	Rural	93.0	na	na	na	na	na

See footnotes following Table 1-3A and additional notes following Table 1-3C

Table 1-3C. Summary of Measurements Comparing Six Freeway Commutes with One Rural Commute (cont'd)

	Commute	Ambient	Out-Car Mean	In-Car Mean	In-Car Range	Roadside Mean	Roadside Range
PM_{10} Metals (ng/m3)							
	Freeway	0.17	na	0.62 (0.26)	0.37 - 0.86	0.28	0.0 - 0.75
	Rural	na	na	na	na	na	na
Chromium (Cr)	Freeway	262.0	na	161 (251)	9.5 - 239	176	67.7 - 239
	Rural	na	na	na	na	na	na
Manganese (Mn)	Freeway	24.2	na	18.8 (21)	9.3 - 25	24.3	2.5 - 46
	Rural	na	na	na	na	na	na
Nickel (Ni)	Freeway	13.3	na	28 (11)	na	0.0	na
	Rural	na	na	na	na	na	na
Lead (Pb)	Freeway	12.8	na	12.5 (8.3)	11 - 14	9.6	1.1 - 16.8
	Rural	na	na	na	na	na	na
Sulfur (S)	Freeway	466.2	na	478 (660)	265 - 639	398	256 - 507
	Rural	na	na	na	na	na	na
In-Traffic Data							
Commute speed, mph.	Freeway	na	na	35.0	na	na	na
	Rural	na	na	47.6	na	na	na
Total miles	Freeway	na	na	75.1	na	na	na
	Rural	na	na	107	na	na	na
Trailing Distance, ft	Freeway	na	na	94.8	na	na	na
	Rural	na	na	193.1	na	na	na
Level of Congestion	Freeway	na	na	3.6	na	na	na
	Rural	na	na	1.0	na	na	na

Content Notes for Tables 1-3A, B, and C:

- All data below the MDL were considered as and entered as 0.0 [see Table 5-1 for starred values that are below the detection limits]
- Means were computed even if the individual input data were below the MQL's
- Data are not necessarily paired, and inter-comparisons should be done with caution
- Some freeway means represent significantly fewer than 6 input values, especially for the metals
- No range is possible for rural data; many rural concentrations were below the MQL
- "Ambient" refers to study monitor data collected at ARB 13th and T St. monitoring site
- Carbon and carbon monoxide data are commute averages of 1.0 minute data
- Benzene data were not available from canister analyses; tabular results shown are from multisorb tubes
- No In-Car PAH analyses were above the MQL (no range reported)
- PAH samples were collected at only 1 roadside site (no range available)
- Only selected samples were analyzed for $PM_{2.5}$ and PM_{10} metals; see Table 5-2 to identify selected samples; means reported represent up to 4 samples for In-Car, but no more than 2 for Roadside
- Data separated by a comma (,) are individual Hour 1 and Hour 2 values
- Data in parentheses () are duplicate analyses
- The $PM_{2.5}$ data are uncertain due to a random leak (see Section 3)
- An "na" means that no data are available

2.0 MATERIALS AND METHODS

2.1 Overview

The Main Study field sampling was conducted from 9/9/97 to 9/15/97 in the Sacramento, California metropolitan area, and from 9/25/97 to 10/3/97 in the Los Angeles area. The field work was conducted by the Research Triangle Institute (RTI) and its subcontractor, Sierra Research. Sierra was responsible for route selection, obtaining the test vehicles, assimilating vehicle and traffic characterization data, and providing drivers and navigators. RTI personnel were responsible for all other aspects, including the collection and analysis of pollutant samples and data. As shown in Tables 2-1A and 2-1B (for Sacramento and LA), a total of 13 commutes were made in Sacramento and 16 commutes is Los Angeles. The balanced factorial design included the same types and number of non-specialized commutes in both metropolitan areas. All commute spanned a 2-hour period to provide a sufficiently long period to be representative of the commute scenario, while collecting sufficient sample materials for subsequent analyses. A variety of Freeway and Arterial commutes were driven, under Rush and Non-Rush hour traffic conditions, and covering both AM and PM periods in both cities. The desire to cover a range of driving scenarios was accompanied by a tradeoff in the limited number of duplicate commutes representing a specific scenario. Only two commutes were made for each factorial scenario, providing information on the estimated pollutant concentration levels, but limiting the ability to conduct robust statistical analyses. Several special purpose commutes were also driven to gather concentration data on specific scenarios, including: (a) a Sacramento rural commute, (b) two Sacramento school bus route commutes, (c) two Los Angeles carpool lane commutes, and (d) two Los Angeles maximum concentration commutes.

Table 2-1A. In-Vehicle Study Commute Scenarios for Sacramento (SAC)

Commute #	Commute Day	Date 1997	Day Week	City	Test Type	Time Period	Roadway Type	Rush Period	Vent Settings	Ambient Data?	Roadside Data?
1	1	9/9	Tu	SAC		AM	Freeway	Non-Rush	High	Yes	Yes
2	1	9/9	Tu	SAC		PM	Freeway	Non-Rush	High	Yes	Yes
3	2	9/10	We	SAC		AM	Freeway	Rush	High	Yes	Yes
4	2	9/10	We	SAC		PM	Freeway	Rush	High	Yes	Yes
5	3	9/11	Th	SAC		AM	Freeway	Rush	Low	Yes	Yes
6	3	9/11	Th	SAC		PM	Freeway	Rush	Low	Yes	Yes
7	4	9/12	Fr	SAC		AM	Arterial	Rush	High	Yes	Yes
8	4	9/12	Fr	SAC		PM	Arterial	Rush	High	Yes	Yes
9	5	9/13	Sa	SAC	Rural	midday	Rural	Rush	High	No	Yes
10	6	9/15	Mo	SAC		AM	Arterial	Rush	Low	Yes	No
11	6	9/15	Mo	SAC		PM	Arterial	Rush	Low	Yes	No
12	7	9/16	Tu	SAC	School Bus	AM	Resid.	Rush	High	Yes	No
13	7	9/16	Tu	SAC	School Bus	PM	Resid.	Rush	High	Yes	No

Table 2-1B. In-Vehicle Study Commute Scenarios for Los Angeles (LA)

Commute #	Commute Day	Date 1997	Day Week	City	Test Type	Time Period	Roadway Type	Rush Period	AER Level	Ambient Data?	Roadside Data?
14	8	9/25	Th	LA		AM	Freeway	Non-Rush	High	Yes	No
15	8	9/26	Fr	LA		AM	Freeway	Rush	High	Yes	Yes
16	9	9/26	Fr	LA		PM	Freeway	Rush	High	Yes	Yes
17	10	9/27	Sa	LA		PM	Arterial	Non-Rush	High	Yes	No
18	11	9/28	Su	LA		AM	Arterial	Non-Rush	High	Yes	No
19	11	9/28	Su	LA		PM	Freeway	Non-Rush	High	Yes	No
20	12	9/29	Mo	LA		AM	Freeway	Rush	Low	Yes	Yes
21	12	9/29	Mo	LA		PM	Freeway	Rush	Low	Yes	Yes
22	13	9/30	Tu	LA	Carpool	AM	Freeway	Rush	High	Yes	Yes
23	13	9/30	Tu	LA	Carpool	PM	Freeway	Rush	High	Yes	Yes
24	14	10/1	We	LA		AM	Arterial	Rush	Low	Yes	Yes
25	14	10/1	We	LA		PM	Arterial	Rush	Low	Yes	Yes
26	15	10/2	Th	LA		AM	Arterial	Rush	High	Yes	Yes
27	15	10/2	Th	LA		PM	Arterial	Rush	High	Yes	Yes
28	16	10/3	Fr	LA	Max Conc.	AM	Freeway	Rush	High	Yes	No
29	16	10/3	Fr	LA	Max Conc.	PM	Freeway	Rush	High	Yes	No

Almost all commutes were led[2] by the specially-equipped test sedan (a 1991 Chevrolet Caprice, designated as Vehicle 1 for all commutes) that was utilized as a mobile sampling platform. This test vehicle was outfitted by RTI to collect inside and outside vehicle integrated samples and continuous measurements for most of the selected pollutants (PM_{10} particle mass and formaldehyde were collected inside only). The inside measurements were made near the driver's breathing zone to estimate the exposure concentrations. Outside samples were collected by drawing air through a sampling line from a point at the base of the windshield at ~16 lpm to a distribution manifold inside the car. The lead vehicle had also been modified by Sierra Research to record vehicular information in 1 minute averages for vehicle speed, spacing to the vehicle in front, and subjective judgments (trained observer) of the Level of Congestion and the type of "target" diesel vehicle leading Vehicle 1. A second vehicle (sedan, SUV, or school bus) typically trailed immediately behind the lead vehicle. The driving protocol was extremely important in defining the primary sources of the concentration levels encountered during the various commutes. An effort was made by the lead vehicle to drive behind a diesel vehicle as often as practical to "over-sample" this emission source *in-situ*. The significance of the lead vehicle was addressed by a detailed review of the driver's view, video tapes for 5 high particle concentration events in Los

[2] Except for the PM school bus commute in which the Caprice trailed the bus, and the carpool lane commutes, where Vehicle 1 traveled the carpool lane and Vehicle 2 traveled the non-carpool slower lanes.

Angeles. Supplemental data were collected by ARB (not part of this study) during the commutes on the fuel analyses used by the test vehicles. These data are given in Appendix B.

Simultaneous integrated samples and measurements for most of the same pollutants were collected in each vehicle, at 2 Roadside sites, and at the most proximal fixed-site Ambient air monitoring station. The Sacramento site was operated by ARB, while the Los Angeles site was maintained by the SCAQMD. The continuous particle counts and black carbon measures were only available in Vehicle 1. Access permits were obtained for Sacramento and Los Angeles from CalTrans to install and service the 2 Roadway sites at the selected locations along the freeway commuting routes. The Roadside monitors were located within 20 feet of the pavement, on the predominantly downwind side of freeway.

Two ventilation control settings in each of the vehicles[3] were standardized to demonstrate their influence on the in-vehicle pollutant concentrations. These settings provided "low" and "high" levels of ventilation with the windows closed. Air exchange rates were measured primarily at a constant speed of 55 mph, although additional tests at 0 and 35 mph were also conducted..

The pollutant measurements and their associated sample collection and analysis methods are given in Table 2-2. The associated supplemental measurements used to characterize the traffic and meteorology are provided in Table 2-3.

TABLE 2-2. Main Study Pollutant Sample Collection and Analysis Method Summaries

Pollutant	Sample Collection	Sample Analysis
PM_{10} Particles (integrated)	MSP 200 4.0 LPM PM_{10} inlets, particle on 37 mm, 3.0 μm porosity Gelman Teflo filters	Gravimetric, on a modified Mettler AT20 microbalance, with computer control
$PM_{2.5}$ Particles (integrated)	MSP 200 4.0 LPM $PM_{2.5}$ inlets, particle on 37 mm, 3.0 μm porosity Gelman Teflo filters	Gravimetric, on a modified Mettler AT20 microbalance, with computer control
Particle Count by size (total counts per minute)	Particle Measurement Systems (PMS) Model LAS-X optical particle counter	Computer data collection and size distribution analyses
Black Carbon	McGee Scientific Aethalometer	5 LPM on quartz fiber tape readings by optical absorption
VOC's	SUMMA passivated 6 liter evacuated canisters, sample rate of 25 cc/min; Multisorbent tubes	GC/MS with SIM enhancement
Formaldehyde	DNPH cartridges, 170 cc/min	Thermal desorption followed by HPLC analysis
CO	Draeger Model 190, diffusion sensing (not pumped)	electro-chemical
Metals in PM_{10} /$PM_{2.5}$ particles	PM_{10} /$PM_{2.5}$ Teflon filters	X-Ray Fluorescence (XRF), energy dispersive

[3] The school bus ventilation was dominated by opening 3 windows half way down on each side of the bus during the commutes - typical of student settings

TABLE 2-3. Supplemental Measurement Method Summaries

Measurement	Sensor	Data Collection/Media
Vehicle 1 Traffic speed in mph	Digital speedometer, mph	Computer, real time, trip averaged
Level of Congestion (traffic density), unitless	Navigator categorical judgment, manual input	Computer storage of binary data
"Target" vehicle type: Diesel Bus, Heavy Duty Diesel Truck, Other Diesel, on Other Vehicle	Navigator categorical judgment, manual input	Computer storage of binary data
Lead vehicle spacing to Vehicle 1 in feet	Laser distance meter in grill	Computer, real time, trip averaged
Vehicles 1 and 2 miles driven	odometers	manual log entry
Video commute record - VHS	Automatic camera with front windshield view field	manual viewing
Air Exchange Rate (at constant 55 mph vehicle speed - not determined during commutes), and selected speeds (0, 35, and 55 mph)	Draeger CO monitor (method of Ott & Willits, 1981)	Internal logger/computer
Meteorology - wind speed, wind direction, relative humidity, and temperature	Obtained from nearest ARB weather station	Computer file, hourly
Commute route narrative characterization - unusual events	Prepared by navigator to supplement video	manual interpretation

2.2 Commuting Routes/Protocols

The selection process for freeway, arterial, carpool lane, school bus, and rural commute routes carefully considered the development of a range of expected exposure concentrations, while being representative of typical Sacramento and Los Angeles commutes. Historical CalTrans count data were examined to identify the potential routes with the highest traffic densities. Highlighted maps of the Sacramento and Los Angeles commute routes are shown in Appendix C. Also shown are the Roadside sites (R1 and R2) and the Ambient sites (A). Commute trips were 120 minutes in length over the selected route, with measurements terminated at the 120 minute point. Each route was driven repeatedly as needed to constitute the total number of miles driven in each 120 minute commute. In all cases the commute route could be driven more than once during the 2 hour period. For non-loop routes, the driver turned around at the ends and retraced the route repeatedly until 120 minutes had elapsed. For loop routes, the driver maintained the same direction for the duration of the commute. The starting direction for each commute was selected based on the travelling with (in the same direction as) the heaviest traffic flow expected for the period for the longest period of time.

2.2.1 Sacramento Routes

- The Freeway commuting route for Sacramento was identical to that used during the Pilot Study. It began at the Clarion Hotel parking lot at 700 16th St., proceeded to the J St. on-ramp on I-5, proceeded South onto East/North bound Bus. 80, merged with I-80, and terminated (vehicles turned around and retraced linearly) at the Madison St. exit.
- The Arterial commute began at the Clarion Hotel parking lot at 700 16th St., proceeded east on H St. thru Fair Oaks Blvd., turning around at El Camino Ave. for the linear retrace return on the same route.
- The School Bus commutes followed a randomly selected Sacramento school system route, starting from the Abe Lincoln school. The AM route pattern was complex (typical, with many bus stops) and is described in detail in Appendix C. The route was driven repetitively for a 120 minute commute. The PM route was somewhat different, but ended at the same school. The bus followed Vehicle 1 (Caprice) for the AM commute, with the order reversed in the PM commute (Caprice following the bus). Passenger ingress and egress was simulated at the regular bus stops by a study technician exiting and then re-entering the bus. No roadside monitoring sites were used during the school bus commutes.
- The Rural commute was a loop located NW of Davis, CA, and began at the small regional airport parking area on Road 95, proceeded North to Road 27, east on Road 27 to Road 98, south on Road 98 to Road 31, west on Road 31 to Road 95, and back to the airport, plus repeats.

2.2.2 Los Angeles Routes

- The Freeway route in Los Angeles covered a large loop, proceeding east (clockwise) in the AM at the Rosemead on-ramp on I-10, South on I-110, East on I-405, North on I-710, East on I-91, North on I-605, and West on I-10 to complete the loop. The PM loop was driven in the reverse direction, starting counter-clockwise.
- The Arterial route in Los Angeles started North on Rosemead from the I-10 underpass, West on Valley Dr., merging with Mission Rd., West on Beverly Blvd., South on Broadway, East on Firestone, South on Avalon, East on Sepulveda Blvd., merging with Willow Rd., North on Lakewood Blvd., and merging with Rosemead at the I-10 underpass.
- The Freeway Carpool route started West on I-10 at the Rosemead on-ramp, proceeding South on I-110 to the Carson, turning around at the I-405 interchange and returning.

2.3 Commute Driving Protocol

The commute driving protocol is a key component, defining the vehicular sources most likely to influence the observed pollutant concentration levels. An important driving factor for all commutes was a focus by the lead vehicle driver to be positioned behind obviously polluting "target" vehicles, whenever possible, to incorporate their influences on in-vehicle concentrations. The guidelines provided to the lead car driver and navigator, included:

1) follow the pre-selected route and position behind a target vehicle whenever possible; the target vehicle was defined as a heavy duty vehicle with diesel exhaust, or other obvious visible (or odorous) vehicular emissions;
2) drive the right hand lane, except when changing lanes to follow or acquire a target vehicle;

3) break off target vehicle pursuit if target vehicle turns off route, can't be followed, drives erratically or unsafely, or appears to modify behavior due to following;
4) change target vehicle if a vehicle with higher exhaust emissions becomes available;
5) drive with normal following distances (like other nearby cars) but not further than about 100 feet behind target vehicle.

Although a few gasoline powered "target" vehicles were noted as being "emitters" (by eye or nose) during the study, the most prevalent visible emitters were diesel vehicles - primarily city buses and heavy duty trucks. This bias toward "high-end" scenarios was intentional. In several cases, however, this proved to be a confounding factor, since the emissions of the vehicle immediately in front of the test vehicles were observed to have a pronounced influence on the commute-average in-vehicle concentrations. A brief 10-minute period (in a 120 minute commute) behind a single, visibly heavily-emitting, diesel city bus can dominate the particle levels for an entire commute average, especially during periods of lower traffic volume (e.g. arterial non-rush). This influence was determined subsequently for a few commutes by a careful review of the in-vehicle video tapes (see section 4.4.1), matched with the continuous pollutant monitoring data. A manual switchbox entry was also tabulated by the Vehicle 1 navigator, which included the category of "target" vehicle immediately in front. The fraction of time (relative to the total commute) that the target switch was set in each position was stored and computed. This permitted compiling the percentage of time behind heavy-duty diesels (HDD) for each commute.

The ability of the driver of Vehicle 1 to select and follow a "target" vehicle was generally much easier in low traffic density settings, especially the ANR and FNR commutes. Conversely, higher traffic density situations, especially the FR commutes, proved much more difficult for the driver to maneuver in traffic. Commutes with minimal traffic (e.g. arterial non-rush) were easier to select a target vehicle, and are the most likely to have the commute-average concentrations influenced by single vehicles. These factors, combined with the substantial contributions for some pollutants made by some "target" vehicles to the inside concentrations, suggests that the non-rush commutes are perhaps the most influenced by the targeted driving protocol. Consequently, some commutes cannot necessarily be considered as "typical" of specific scenarios, but as less probable "high-end" cases.

Another important related consideration in reviewing the concentration results was the tandem nature of the commutes, with a fully instrumented lead vehicle (Vehicle 1) always trailed by Vehicle 2 (sedan, SUV, or school bus). This is especially significant when a "target" vehicle is being followed by Vehicle 1, with Vehicle 2 trailing at some greater distance. Two factors should be kept in mind in this situation, (1) the emissions from the "target" vehicle are typically diluting continuously after emission, such that Vehicle 1 may be more likely to be exposed to higher concentrations than Vehicle 2, and (2) the exhaust emissions from Vehicle 1 were typically sampled by Vehicle 2 (but not vice-versa). The degree to which Vehicle 1 may have been more exposed to target vehicles than Vehicle 2 was not determined (not a study objective). Similarly, determining the influence of Vehicle 1 on Vehicle 2 was not a study objective.

2.4 Pollutant Measurement Method Descriptions and Performance Data

2.4.1 In-Vehicle / Outside-Vehicle Sampling

Inside sampling in each vehicle was conducted at a location immediately behind the center of the front seat. All samplers with pumped systems were exhausted external to the vehicle. While this had some impact on the AER (the influence from the total flow of these samplers (~10

lpm) was estimated to be less than 1%, based on the interior volumes of the vehicles and the relatively high AER's during commuting. Outside sampling required the use of a sampling line operating with sufficient flow (~16 lpm) to rapidly transport the air from near the base of the windshield to the distribution manifold. Large-bore solenoid valves were used to switch the air stream from inside to outside, controlled by a time signal from the onboard laptop computer. The same program stored zeros (inside) and ones (outside) along with the LAS-X count data to simplify data reduction. While gas phase pollutants were not expected to have significant losses through the inlet line, it was expected that some particle losses would occur, as a function of particle size. A particle loss test for the inlet system is described in section 2.4.8.1.

2.4.2 Roadside and Ambient Sampling

Roadside sampling during freeway commutes required encroachment permits from CalTrans. Since the sampling stations were supported on a simple signpost, the impact of the stations on the local landscape was imperceptible. Permission to locate the units during arterial commutes was informal, and required only verbal permission in all cases. Access to the ambient stations was obtained by the ARB project officer, from the local ARB group responsible for the station. Roadside and ambient site sampling units were completely battery-powered and self-contained. This permitted the units to be prepared and checked at the central work station (motel) prior to transporting to the sampling site. The initiation and termination of sampling for each measurement were manual, however, and required that the field staff arrive at the roadside or ambient site very close to the start or end time to define the nominal 120 minute sampling period. An acceptance window of 10 minutes was allowed for the start and end times, suggesting that a maximum allow clock time error would be 20 minutes out of 120, or approximately 15 %. In almost all cases, the actually deviation from the commute start and end was less than 10 %.

2.4.3 Volatile Organic Compounds (VOC's)

2.4.3.1 Method Description - Air samples for monitoring the target VOC's were collected in both 1.8 L and 6 L SUMMA passivated stainless steel canisters. Restrictive orifices were used to control air flow into the canisters at ~25 ml/min during the 2-hour sampling period. Canister samples were returned to the laboratory. Canister samples were analyzed within 8 days of collection.

Prior to use, canisters were cleaned by heating to 130 °C in an oven for 4 hours while connected to a vacuum manifold. Canisters were then evacuated to 0.05 mm Hg vacuum. Restrictive orifices constructed and calibrated at RTI were attached to each canister in the field. During sample collection, a rotameter was used to verify air flow rates.

VOC's in canister samples were cryofocused then analyzed by gas chromatography/ mass spectrometry (GC/MS). Selected ion monitoring (SIM) was used to enhance method sensitivity. Analytical conditions were described in detail in the Pilot Study report. During analysis, a portion (200 ml) of the sample plus a known concentration of the external quantitation standard were cryogenically trapped then injected into the GC column for separation and analysis. VOC identifications were based on chromatographic retention times relative to the external quantitation standard and relative abundance's of the selected ion fragments. Ion fragments were selected based on previous project work with the target chemicals. Quantitation was performed using chromatographic peak areas derived from the selected ion profiles. Specifically, relative response

factors (RRF's), or first order linear regression, for each target compound were generated from injections of canister standards prepared at 5 different concentrations (~0.5 to 50 ng/L).

Mean values and standard deviations of the RRF's were calculated for each target VOC. The calibration curve was considered acceptable if the standard deviation for each relative response factor was less than 25%. During each day of analysis, an additional medium level calibration standard was analyzed. If the RRF values for this standard was within ±25% of the average RRF, the GC/MS system was considered "in control" and the mean RRF's was used to calculate the concentration of the target VOC's in a sample (C_{TS}).

During this study, the following quality control (QC) samples were prepared and analyzed to demonstrate method performance.

- Field controls (FC) were used to evaluate method recovery. These are canisters spiked with target VOC's at known concentrations. These samples are shipped to the field and handled exactly as field samples except that the valves are not opened.
- Field blanks (FB) were used to evaluate background contamination. These are unspiked canisters that are prepared by filling clean evacuated canisters with a volume of approximately 4.5 liters of VOC-free humidified nitrogen. These canisters are shipped to the field and handled exactly as field samples except that the valves are not opened.
- Field duplicates were field samples collected side-by-side to assess sampling precision.
- Method quantitation limits have been set to the concentration of the lowest calibration standard.

2.4.3.2 VOC Performance Data

TABLE 2-4. Method Performance Data for VOC Canister Samples

Analyte	Method Quantitation Limit, MQL ($\mu g/m^3$)		Field Blank Concentration ($\mu g/m^3$)		Field Control % Recovery (n = 3)		% RSD Duplicate Samples	
	SAC[a]	LA	SAC (n=6)	LA (n=6)	SAC (n=3)	LA (n=3)	SAC (n=5)	LA (n=4)
Isobutylene	0.22 (0.44)	0.22	NR[b]	0.45	c	-	4.5	6.3
1,3-Butadiene	0.30 (0.60)	0.30	NR	<MQL	91	103	7.9	6.9
Acetonitrile	0.70 (1.4)	0.70	NR	<MQL	-	-	6.6	12
DCM	1.1 (2.2)	1.1	NR	<MQL	-	-	30	9.3
MTBE	1.0 (2.0)	1.0	NR	<MQL	96	111	6.1	6.5
ETBE	1.0 (2.0)	1.0	NR	<MQL	92	113	na	na
Benzene	1.1 (2.2)	1.1	NR	<MQL	95	116	5.5	4.9
Toluene	1.1 (2.2)	1.1	NR	2.5	101	105	8.4	4.5
Ethylbenzene	0.80 (1.6)	0.80	NR	<MQL	-	-	3.0	3.1
o-Xylene	1.2 (2.4)	1.2	NR	<MQL	108	116	3.8	4.1
m,p-Xylene	1.1 (2.2)	1.1	NR	<MQL	107	110	3.3	3.4
TCFM	0.37 (0.70)	0.37	NR	<MQL	-	-	na	na

Notes: a MQL based on lowest calibration standard. Lowest calibration standard varied for Sacramento data. Numbers in parenthesis indicate lowest calibration for some sets of data.
b NR - not reported, field blanks contaminated during preparation process.
c (or no entry) - no data, compounds were not included in control mixture or not detected in sample.
na – insufficient data above the MQL to compute

The two slightly elevated LA field blanks (isobutylene and toluene) were unexpected, and attributed to a possible field contamination problem. Note also in Table 2-4, that two different values are listed for the MQL for the Sacramento VOC samples. This is due to instrument problems experienced during the analysis of some of the Sacramento canister samples. A leak in the valve system supplying the calibration gas to the GC/MS cryo-focusing interface unit resulted in the loss of calibration gas while switched to the off-line position. This leak only affected the total number of runs that could be made from each calibration cylinder and not the accuracy of delivery, as long as the cylinder pressure was sufficient to drive the flow controller. However, this did require more frequent calibration of the system since the calibration cylinder had to be replaced more often. During one of these calibrations, the lowest calibration point was erroneously omitted from the calibration curve. Since the MQL was determined by the lowest calibration point, this necessitated that the MQL for that set of data be increased above the MQL

for the other sets. All affected samples were not reanalyzed due to time constraints for recycling the canisters for shipment to the field for collection of additional samples.

2.4.4 Particle Mass

2.4.4.1 Method Description - The filter collection and weighing methods for gravimetrically-based PM_{10} and $PM_{2.5}$ particles measurements are based on methods that have been used previously at RTI. The methods have been validated during the past three years on two large-scale exposure studies conducted for the U.S. EPA and a commercial client. The extremely short sampling periods proved very challenging, especially for the $PM_{2.5}$ and PM_{10} samplers. This had not been attempted before, and required extremely close attention to the performance of the electronic balance during the weighing process by the data computer software. This was complicated by the need to weigh filters on-site in only a modestly temperature and humidity controlled environment (the motel room). It had already been demonstrated that the Teflon sampling substrates did not significantly change tare weights (< 2 μg) with even large changes in relative humidity changes (20 to 80% Rh). It was observed, however, that the electronic balances worst enemies were static charge and ambient temperature effects on the electronic circuitry. Previous redesign of the balance chamber had successfully resolved the static charge effects, but several successive efforts in redesigning the balance control software to accommodate ambient temperature fluctuations (especially those caused by drafts) were required to adequately bring the replicate weighing precision below 2 μg.

Detailed specifications for the RTI PM_{10} and $PM_{2.5}$ particle exposure monitoring systems are provided in Table 2-5. The MSP model 200 Personal Exposure Monitor (PEM) inlets for PM_{10} and $PM_{2.5}$ are based on standard impactor theory, and demonstrate excellent cut point sharpness. In order to verify that leaks in the PEM inlets observed in the Pilot Study had been corrected, a brief collocated field test was conducted at the RTI facility in North Carolina. Six PEM units were operated simultaneously with 3 collocated EPA $PM_{2.5}$ reference samplers, and demonstrated no leaks, excellent precision, and excellent agreement with the EPA devices. The report of this comparison test in provided in Appendix D.

Although $PM_{2.5}$ cut point impactors can exhibit substrate overloading during extended use, the combination of an additional "scalping" stage, and the short duration of sampling proposed in this study eliminated this concern. The MSP inlets are relatively wind speed insensitive, but the turbulence outside a moving vehicle is undoubtedly too harsh an environment for accurate coarse particle sampling. Thus, the inlets were not used external to a moving vehicle. Outside PM_{10} measurements were not made. $PM_{2.5}$ inlets collected particles off of the manifold after air was drawn in from the outside.

The inlets incorporate 10 holes for the 4 lpm version that directs the inlet flow toward an oil-coated, sintered metal impactor ring. After impaction to achieve the design cut point, the remaining particles are drawn to the membrane filter substrate located in the inlet base. The oiled surface is clean and replenished prior to each sampling event. The inlets are placed in Ziplok bags after preparation to prevent stray particles from entering through the jet holes.

During monitoring, an electronically flow-controlled battery operated pump (modified BGI model AFC123) was used to sample air through the portable impactors. The impactor contained a 37-mm diameter Teflon filter having a 3-μm pore size. For both the PM_{10} impactor, and the $PM_{2.5}$ impactor, a constant flow rate of 4.0 lpm was used.

Flow rate checks were performed with a specially-designed orifice that seals over the MSP inlet. The pressure drop across the orifice is monitored with a Magnehelic gauge. The pressure drop versus flow rate calibration for the orifice is established against a NIST-traceable Gilibrator bubble flow meter. System performance data are provided in Table 2-6.

Filters were weighed both before and after sample collection using a Mettler AT20 balance with a ±2 μg weighing precision in a single measurement. The balance was connected to a microcomputer with weighing software developed for gravimetric analysis of filters. All weighings were conducted in the field in the motel work room. Although this room was only equipped with a standard heating/air conditioning unit, this degree of conditioning was determined to be adequate to conduct the gravimetric analyses. The Pilot Study had demonstrated that accurate and reproducible gravimetric analyses could be accomplished outside a stringently controlled environment by, (a) using the hydrophobic Gelman Teflo® filters, (b) maintaining the relative humidity below 40 % Rh, (c) eliminating room drafts that confound the electronic temperature control circuitry of the Mettler balance, (d) using Teflo® lab blanks to evaluate substrate changes with time. Filters were equilibrated in the work room for at least 12 hours before weighing. Once tared, all filters were inspected for holes or other imperfections prior to use and were kept in a barcode-labeled petri dish.

Filters were weighed in sets of ten as follows: 1. The balance was zeroed and the calibration checked using a NIST-traceable, class S-3 weight (200 mg). If the zero check was within ±0.004 mg and the 200 mg weight within ±0.002 mg then the balance was "in control" and filters were weighed. If these specifications were not met the balance was recalibrated. 2. Each filter was weighed and the weight recorded once the computer recognized a stable reading (1-2 min). 3. After each set of ten filters was weighed, the zero was checked to within ±4 μg and a 200 mg weight to within ±0.002 mg. If either the zero or the 200 mg weighing failed their test, then the zero/calibration was repeated and the previous set of filters was reweighed.
QC checks included multiple weighing tests with a dedicated filter, and spot checks (reweighing every 20th) of filter weights.

Outside $PM_{2.5}$ sampling was accomplished by connecting the inlet to the outside sampling manifold (see section 2.4.1) using the standard flow calibration adapter provided by MSP. Minimal losses were expected using this approach, as compared with trying to place the inlet on the outside of a moving vehicle. Losses in the sample line and manifold for the outside $PM_{2.5}$ samples were crudely estimated to be 19 to 21%, based on LAS-X count data (see Section 2.4.8.1). These correction calculations based on particle count data are only approximate, however, and were not considered sufficiently accurate to use as subsequent corrections for the gravimetric data. The reported outside $PM_{2.5}$ data in all tables (and the $PM_{2.5}$ data used in all analyses) are consequently <u>not</u> loss-corrected.

TABLE 2-5. RTI PM_{10} and $PM_{2.5}$ Particle Monitoring System Specifications

Parameter	Specification
Inlet type	MSP, Corp. model 200
Aerodynamic Cutpoints (D_{50})	PM_{10} & $PM_{2.5}$
Cutpoint accuracy	+/- 0.2 µm
Impactor coatings	Silicone oil
Filter type	Gelman 37 mm, 3.0 µm porosity Teflon
Pump Source	modified BGI model AFC123 w/ feedback flow
Flowrate	PM_{10} - 4.0 liters/min; $PM_{2.5}$ - 4.0 liters/min
Flowrate stability	+/- 5% up to 25 inches of H_2O
Battery Type	4 alkaline AA
Battery life, continuous	~30 hrs at 70 °F

2.4.4.2 Particle Mass Performance Data

TABLE 2-6. Summary of Method Performance Data for Particle Mass Samples (PM_{10} and $PM_{2.5}$)

	Sacramento	Los Angeles
% of samples collected within flowrate specifications (external flow into inlets)	PM_{10} - 100 % $PM_{2.5}$ - 100 %	PM_{10} - 100 % $PM_{2.5}$ - 100 %
% of samples collected under acceptable conditions	PM_{10} - 100 % $PM_{2.5}$ - 100 %	PM_{10} - 100 % $PM_{2.5}$ - 100 %
% of sample weighed with "in control" calibration	100 %	100 %
Precision of every 10th filter replicate weighing (bases for MDL):	s = 3.6 µg	s = 2.2 µg
% CV of duplicate field samples (above MQL)	PM_{10} - 20.3 % $PM_{2.5}$ - 10.3 %	PM_{10} - 4.0 % $PM_{2.5}$ - 8.5 %
Mean mass on field blanks	+ 0.5 µg	- 0.5 µg
Estimated Method Quantitation Limits (MQL's)[b] in $\mu g/m^3$	PM_{10} - 19.7 $PM_{2.5}$ - 19.7	PM_{10} - 13.0 $PM_{2.5}$ - 13.0
% of samples with concentrations greater than MQL	PM_{10} - 64 % $PM_{2.5}$ - 13 %	PM_{10} - 100 % $PM_{2.5}$ - 97 %

Notes: MQL computed as 3 times MDL

[b]% CV for $PM_{2.5}$ in Sacramento estimated, since collocated pairs concentrations were above the MDL, but below the MQL

2.4.5 Formaldehyde

2.4.5.1 Method Description - Formaldehyde was monitored inside the vehicles, at roadside sites, and at the ambient station during each test drive. Formaldehyde in air samples were collected by passing air through DNPH-coated Sep-Pak cartridges (Water Associates, Milford, MA). Samples were collected at a flow rate of approximately 300 ml/min using a battery-powered low volume pump. Samples were collected for a 2-hour period to give a nominal volume of 36 L. Flow rates at the cartridge inlet were measured before and after sample collection using calibrated rotameters with a fixed-orifice bypass tube. System performance data are given in Table 2-7.

DNPH/formaldehyde derivatives on sample cartridges were extracted by eluting each cartridge with 5 ml of HPLC grade acetonitrile into a 5 ml volumetric flask. The final volume is adjusted to 5.0 ml and the sample aliquoted for analysis. DNPH/formaldehyde derivative in sample extracts were analyzed by HPLC with UV detection. Certified solutions of the DNPH/formaldehyde derivative were used to prepare the calibration solutions. DNPH/formaldehyde derivatives in sample extracts were identified by comparison of their chromatographic retention times with those of the purified standards. Quantitation was accomplished by the external standard method using calibration standards prepared in the range of 0.02 to 15 ng/µl of the derivative. Standards were analyzed singly for the formaldehyde/DNPH derivative and a calibration curve calculated by linear regression of the concentration and chromatographic response data. To be acceptable the calibration curve needed to give an R^2 greater than 0.998.

To demonstrate on-going analytical performance, a calibration standard was analyzed each day prior to the analysis of any sample and after every 10 samples. The calibration was considered "in control" if the measured concentration of the formaldehyde derivative in the standard was 85 to 115% of the prepared concentration.

2.4.5.2 Formaldehyde Performance Data

TABLE 2-7. Method Performance for Formaldehyde Samples

	SAC	LA
Estimated Method Quantitation Limit, MQL	3.1 µg/m^3	3.1 µg/m^3
% of Samples with formaldehyde levels > MQL	96 %	98 %
% Recovery from Field Controls (n=3, 3)	± 104 %	± 105 %
Amount on Field Blanks (n=4, 4)	0.16 µg/m^3 for a 24 L sample	1.3 µg/m^3 for a 24 L sample
% CV of Duplicate samples (n=3, 4)	5.0 %	9.6 %

2.4.6 Carbon Monoxide

2.4.6.1 Method Description - Carbon monoxide was measured inside of the vehicles, outside of the vehicles, at the roadside sites and at the ambient sites using Draeger Model 190 carbon monoxide monitors/data loggers with extended memory. The monitors are pocket size,

sensing and logging devices with accuracy reported by the manufacturer as ±2 ppm CO. The monitors are powered by a single 9 V alkaline battery. The monitors utilizes a three-electrode electrochemical sensor for continuous measurement of CO. A scrubber containing charcoal and Purafil is used on the monitor inlet to reduce interferences. An integral data logger records sensor measurements 120 times per minute. These values are averaged by the monitor and 1 minute average values are stored by the monitor data logger. Stored values are downloaded at the end of the monitoring period via an RS-232 interface to a portable computer using software supplied by National Draeger, Inc.. Results will be reported as 120 one- minute data files, one hour averages, and peak CO concentrations.

Two CO monitors were used for each vehicle to monitor inside and outside CO concentrations simultaneously. Teflon sampling lines were used to draw air sequentially, first near the driver's breathing zone, and then from the vehicle exterior via a sampling manifold. A computer controller electronic timer was used to switch solenoid positions between the interior and exterior sample line every 5 minutes. Fixed site CO monitors were placed in "weather tight", insulated sampling boxes to minimize effects due to ambient outdoor temperatures and moisture.

Prior to initial use in the field, each CO monitor was calibrated using certified carbon monoxide gas standards at concentrations of 0, 2, 10 and 21.5 ppm. In addition to the weekly checks, a zero and span (21.5 ppm) check was performed at the start and the end of each test drive. At the start of the test drive, the zero and span of the monitor was adjusted to give readings of zero and 21.5, respectively. At the end of the test drive, no adjustments were made for the zero and span, rather reading were recorded on log sheets prepared for this purpose.

2.4.6.2 Performance Data

The CO monitors worked well during the study, with two missing data files resulting from an computer file loss during data transfer. No data required modifications resulting from zero and span drifts (all monitors were calibrated prior to each commuted). The MQL for the Draeger monitor of 2.0 ppm provided a relatively high percentage of data above the MQL in Sacramento (42 %), as compared to Los Angeles (74 %). The majority of the data below the MQL were at the Ambient sites.

2.4.7 Particle Elements

2.4.7.1 Method Description

The $PM_{2.5}$ and PM_{10} Teflon filter samples for Sacramento and Los Angeles were submitted to the Desert Research Institute (DRI) for energy-dispersive X-Ray Fluorescence (XRF) analysis. The standard analysis protocol (A) with a counting time of 8 hours/filter was utilized, since it was determined that longer, more expensive protocols would not be cost effective with the small loadings present from the in-vehicle samples. A determination was made that the reported MQL for these samples was reasonable for this study and would be cost-effective for quantifying the concentration levels of the target metals - Cd, Cr, Mn, Ni, Pb, and S. The $PM_{2.5}$ and PM_{10} filter samples were analyzed by DRI for a complete suite of elements, Al, Br, Ca, Cd, Cl, Cr, Cu, Fe, K, Mn, Ni, P, Pb, S, Si, Sr, Ti, and Zn. The summaries in section 3 and the data analyses in section 4, focus only on the target metals.

Concentrations were provided by the Desert Research Institute in $\mu g/m^3$, based on a measured deposit area of 7.57 cm^2 and using the sampled volume and deposited mass data. Concentrations for Al, Si, P, Cl, K, and Ca values determined by XRF on PM_{10} samples were

adjusted for large particle self-absorption using a theoretical self absorption correction. This adjustment is a function of particle size distribution and composition. Since the actual particle size distribution and composition is unknown, the uncertainty of these adjustments is up to 25%, and is reflected in the reported uncertainty. Particle size effects for Na and Mg were so large and variable that accurate corrections for these two elements could not be made. Their raw, uncorrected concentrations were reported, but they should not be considered quantitative. Four of the 28 samples that were submitted for replicate analysis did not pass DRI's normal criteria for replicate analyses. Examination of the filters and the data showed that this was due to an uneven distribution of fine particles on the filters, and concentrations near the detection limit. The overall method performance data are given in Table 2-8.

2.4.7.2 XRF Elemental Performance Data

TABLE 2-8. Method Performance Data for XRF Elemental Particle Sample Analyses

		PM_{10}			$PM_{2.5}$			Filter Blanks (ng/sample) (ng/m^3)
Analyte	Method	MDL (µg/m^3)	MQL (µg/m^3)	%>MDL	MDL (µg/m^3)	MQL (µg/m^3)	%>MDL	
Pb	XRF	0.06	na	2%	0.06	na	1%	< 0.7 ng/filter <0.01 ng/m^3
Cd	XRF	0.2	na	0%	0.2	na	0%	< 0.2 <0.003 ng/m^3
Cr	XRF	0.8	na	0%	0.8	na	0%	< 0.4 < 0.008 ng/m^3
Mn	XRF	0.07	na	0%	0.07	na	0%	< 1.0 < 0.02 ng/m^3
Ni	XRF	0.045	na	1%	0.045	na	0%	< 2.0 < 0.04 ng/m^3
S	XRF	0.08	na	100%	0.08	na	99%	na[5]

Notes: 1. Method Detection Limit is calculated as 3x the standard deviation of a background count for each filter. These detection limits varied; the median value is shown above.

2. The only significant elemental analysis data were obtained for sulfur, which was present in virtually all the filters. Table 2-7 shows the percentage of samples above the MDL. The MDL was determined as three times the standard deviation of the background on each individual filter. Since these were different for each sample, the value shown in Table 2-7 is an estimate based on the median value. The uncertainty in the sulfur concentrations is given by the laboratory as approximately 5% of the concentration value.
3. One $PM_{2.5}$ sample was flagged in the laboratory as having large particles visible on it. Three PM10 samples were flagged as having visible metallic particles on them. However, the data from these samples did not change any reported results.
4. Blank levels determined using ICP/MS; see lab report in Appendix E
5. Blank level for S by ICP/MS not available - inadvertently not determined

2.4.8 Total Particle Count

2.4.8.1 Method Description - The LAS-X optical particle counter (Particle Measuring Systems, Boulder, Colorado) was mounted on a specially-designed platform immediately behind the front seat in Vehicle 1. The instrument was operated off of the power inverter that was located in the trunk of the test vehicle. The total counts of fine particles both inside and outside of the vehicle were measured continuously in the size range from 0.15 to 2.5 μm, by summing the twelve individual size bins in this range[4]. Measurements were made with the inlet cycling between the inside and the outside of the vehicle. Collected data was output in 60 one-minute total particle count values for each bin, as count totals for each minute (inside and outside), plus the integrated bin and commute averages. Mean total particle counts/minute were computed and reported for each 2 hour commute. The particle concentration in particles/cc can be computed by dividing the one minute count totals by the sampled volume of 60 cm^3. Particle count size distributions were reported by plotting calibrated bin size in micrometers versus the one minute average bin counts.

Outside air was drawn through the sampling manifold. An initial test was performed to estimate the particle fractional losses through the outside inlet line and manifold for each bin size. These loss data are shown in Appendix F, and permitted LAS-X bin count corrections to be made subsequently. The individual bin losses through the sampling line werecomputedapproximately(based on count) over the 0.15 to 2.5 μm size range varied from 5 to 27 %. The LAS-X "outside" count data reported in all subsequent summaries were corrected for line losses by particle size.

A crude estimate of the mass lost during gravimetric sampling was also made, using the LAS-X particle penetration data in Appendix F. Based on the min to max range of measured particles/cm^3 (by bin size) from all of the size distributions shown subsequently in Section 4, composite mass losses from 0.15 to 2.5 μm for integrated $PM_{2.5}$ particles passing through the sampling line were crudely computed to be approximately 19 - 21 %. The computation proceeded as: (a) (particles/cm^3) x (1 – fractional penetration) = particles lost/cm^3 ; (b) (volume in cm^3 of a single particle of the mean bin diameter computed) x (a representative density by size (1.7 g/cm^3) = mass of a single particle, g; (c) (particles lost/cm^3) x (sampled volume, cm^3) = total particles lost/bin; (d) (total particles lost/bin) x (single particle mass/particle, g) x 10^6 = mass lost/bin, μg for bin X; (e) sum mass lost over all bins; (f) repeat the calculations to determine total mass for 100% collection across all bins; and (g) dividing total mass lost by estimated total $PM_{2.5}$ mass collected, expressed as a % . This loss estimate was based on conversion of total particle volume to mass using the same estimated ambient particle density (1.7 g/cm^3) for all particle sizes (as a worst case). Since in reality the sampled ambient distributions and particle densities vary from sample to sample, the accuracy of this mass loss estimate is considered reasonable, but uncertain. Thus, this estimated mass correction was not used to correct the actual gravimetric results.

Prior to the study, the LAS-X instrument was calibrated in the laboratory at Aerosol Dynamics Inc. The individual optical channel bin calibrations were performed using a differential mobility optical particle size spectrometer (DMOPSS) system, which was developed and deployed for two atmospheric visibility studies to provide*in- in-situ* calibration of optical counters for precise size distribution measurement (Stolzenburg et al., 1995) with ambient Berkeley, CA

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[4] The upper bin size limits for the LAS-X in this range are nominally: 0.15, 0.18, 0.23, 0.28, 0.35, 0.45, 0.58, 0.73, 0.90, 1.13, 1.38, 1.75, 2.25, and 2.58 μm, for a total of 14 bins.

aerosols and with dioctyl sebacate aerosols. Calibrations were conducted using both dioctyl sebacate, an aerosol with a refractive index of 1.45, with size-classified ambient Berkeley aerosols, andsize- size-classified California vehicular aerosols from a local Berkeley tunnel study. The technical details of these calibrations were provided in a separate report (Kreisberg et al., 1997) to the ARB project officer as part of the final subcontract report prepared by Aerosol Dynamics.

During the study, fine particle measurements were made by sampling with a single LAS-X optical counter both inside and outside the vehicle. Data were collected with 15 s time resolution, then combined into 1 min averages. The total count data for each of the one minute intervals were computed by summing the bin counts from 0.15 to 2.5 μm. The 1 min. count totals were averaged for each commute to provide means inside and an outside (Vehicle 1) in units of total particle counts/min. These are reported subsequently in the summary tables in Section 3. Mean total particles/cm^3 /min was determined by dividing the total interval count by the 60 second sampled volume of 60 cm^3 .

Particle count size distributions were constructed by using the individual bin counts and their associated particle diameters (optical, not aerodynamic). The Aerosol Dynamics bin calibrations (see Appendix F) for ambient California aerosol was used for distributions collected when no specific "target" was immediately in front of Vehicle 1. When a vehicular target was identified (especially by an elevated back carbon level), the bin calibration for vehicular aerosol was also provided graphically. The LAS-X response to ambient aerosol versus vehicular aerosol is substantially different, especially in the (optical) particle size range (<~0.8 μm) reported by Birch and Cary (1996) for carbonaceous diesel emissions. Since diesel exhaust aerosol tend to be lighter, long chain agglomerates, their sizing by an optical particle counter must be viewed cautiously, especially as compared to their aerodynamic diameter.

Integrated mass concentrations were estimated from the LAS-X count data in the Pilot Study report by applying a composite density, based on the calibrations from the "real" California ambient and vehicular aerosols. The proportion of ambient and vehicular aerosol was adjusted based on the comparison with the gravimetric $PM_{2.5}$ mass concentration data. From these computations, it was crudely estimated that on a commute-average basis, the sampled in-vehicle aerosol was ~25 % vehicular and 75 % ambient. The close proximity of Vehicle 1 when following a "target" vehicle in the Main Study, combined with the elevated black carbon levels, suggested that this estimating procedure for mass concentrations was not sufficiently robust to merit repeating.

2.4.8.2 Performance Data

The flow calibration of the LAS-X sample flow rotameter was checked with a bubble flow meter at the start of field sampling in both Sacramento and Los Angeles, and found to be within 10%. Daily tests were not done. The particle bin size calibrations performed by Aerosol Dynamics prior to the Pilot Study were the only accuracy tests performed for this unit. Field accuracy checks were not possible. Prior to the start of each commute, a HEPA filter was applied to the sampler inlet to verify that the total particle counts returned to zero for all commutes (they did). This test also permitted a time synchronization check against the built-in clock. Overall, the unit worked flawlessly, except for the five Sacramento commutes (#'s 4, 6, 7, 8, and 11) when the inverter power from Vehicle 1 failed.

2.4.9 Black Carbon

2.4.9.1 Method Description - The concentration of elemental, or "black" carbon was measured semi-continuously using an Aethalometer (Magee Scientific, Berkeley, CA). This is a commercial instrument that examines the blackness of a filter as the sample is collected. A prototype developed at Lawrence Berkeley Laboratories was used in the 1986 ARB-sponsored Carbon Species Method Comparison Study, and was able to resolve single diesel trucks in the parking lot next to the sampling site. The Aethalometer was mounted on a specially-designed platform immediately behind the front seat in Vehicle 1. The instrument was operated off of the power inverter that was located in the trunk of the test vehicle. The instrument was operated using the manufacturer's calibration and internal software. Measurements were taken with a 1 min time resolution. Measurements were made with the inlet cycled between inside and outside of the vehicle to give the inside/outside ratios as a function of time and vehicle driving conditions. Data output is 60 one-minute values for each commute (inside and outside), plus commute averages. Outside air was drawn through the sampling manifold.

2.4.9.2 Performance Data

The instrument operational software automatically tests internal performance parameters including lamp voltage and sampling flowrate, and compares the parameters against acceptance limits. These internal tests were summarized as part of the electronic data files, and indicated that no data were collected outside the manufacturer's limits. No field calibration of the instrument was attempted, nor were flow rate test done, other than those done by the instrument as self-tests. While it is assumed that the internal calibration is reasonable for predicting mass concentrations of black carbon, the most important aspect of these data are the relative concentrations with time. Overall, the unit worked well, except for one commute (#6) when the inverter power from Vehicle 1 failed, and one commute (#23) in which the test HEPA filter was inadvertently left in place for the entire commute.

2.4.10 Air Exchange Rate (AER)

2.4.10.1 Method Description - Air exchange rates for the test car under the three ventilation settings were measured using a modification of the CO decay method of Ott and Willits (1981). The procedure was implemented as follows:

- travel to an isolated location with minimal traffic ;
- set the selected ventilation setting in the test car and begin to drive the car at the desired speed (0 to 45 mph);
- release CO into the cabin of the automobile to a concentration of approximately 20 to 30 ppm;
- maintain the desired speed of the car (0, 35, or 55 mph);
- monitor CO concentrations in the cabin of the car with the Draeger CO monitor; and
- compute the AER [air changes / hour], as: $AER = (1/t) \ln (C_i / C_f)$

where t = decay time (h), and C_i , C_f are the initial, final concentration of CO in ppm.

2.4.10.2 AER Performance Data

The precision of the air exchange rate method is a function of the precision of the Draeger CO monitor used in the tests. Since the released CO concentrations were all substantially above the MQL (a 50 ppm CO blend was released), the detection limit of the monitor was not a factor.

The estimated coefficient of variation for air exchange rate measurements based on successive determinations at the same constant speed and vent setting was 9.6 %.

2.5 Vehicular Data

2.5.1 Method Description - Vehicle speed was recorded using a digital sender mounted on the drive-shaft for Sedan 1 and custom signal-conditioning circuitry. The signal from the OEM speed sender was also recorded as a backup. A grill-mounted laser range finder made to custom order for Sierra Research by Laser Atlanta, measured following distance from the car ahead. Accuracy of the measurement is approximately two feet. Lateral and longitudinal accelerometers were used to automatically record total acceleration (not a reported variable for this study). All data were recorded once per second. Note that in-vehicle traffic data represent the vehicular conditions that Vehicle 1 (and Vehicle 2, when traveling together) were actually "exposed to" during each commute, as opposed to fixed-location, traffic loop counters that define the count (and occasionally speed) at one point). In-vehicle measures can only indirectly provide relationships with traffic count (not a study design objective – see Table 1-2), but are more desirable than the incomplete pictures provided by CalTrans loop counter locations for a given commute route.

During on-road data collection, the test vehicle was driven by a two-member team that is familiar with the on-board equipment and drive protocols. The principal responsibility of the driver was, of course, to drive safely. The second technician served as a navigator and "observer," and used a manual data entry switch box to log information of the selected parameters. These manual data included: Level of Congestion[5] [a subjective categorical traffic density rating made by the Sierra navigator with 1 as no congestion, and 6 as extremely congested;] and Target Vehicle Type [subjective categorical identification as: 0 – no target, 1 – light duty vehicle, Heavy Duty Diesel (HDD) truck,2 – smoking light duty vehicle, 3 - Other Heavy Duty Vehicle, 4 - Light Duty Diesel, 5 - Diesel Bus, 6 - Heavy Duty Diesel (HDD) truck, or and the time trailing immediately behind each type]. When necessary, the navigator kept a manual record of unusual events during each test drive. All drives were videotaped for later examination of any unusual events or to ascertain additional information about the test drive. Only the video tapes from the five highest particle concentration commutes in LA were actually reviewed. The CalTrans hourly vehicle count data (from freeway loop counters) were found to be of limited value in the Pilot Study, since they are routinely collected only on an infrequent basis and don't necessarily represent the entire commute routes. This made it impossible to directly relate the CalTrans data to the vehicular data collected in the study. The only utility of the CalTrans data (see Appendix A, Pilot Study Report) was to demonstrate that the selected 2 hour commute periods reasonably defined the peak traffic periods. No CalTrans data were collected or evaluated during the Main Study. The limitations and caveats of using an instrumented platform to collect in-traffic vehicular data are summarized by Austin et al (1993).

The Sierra navigator notes (event log) for each commute are provided in Appendix G. These notes provided information of "unusual" events during each commute, and would be especially useful if further interpretations of the archived video records are attempted.

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[5] The term "Level of Congestion" used in this report corresponds to the six US Department of Transportation level of service categories defined in the "Highway Capacity Manual", special report 209 by the Transportation Research Board of the NRC (Washington, DC) in 1985. Although level of service is strictly defined from a fixed and elevated observation point, Level of Congestion was used in this study from the mobile Sierra navigator's point of view. The guide illustrations for the 6 congestion levels is provided in Appendix G.

2.6 Meteorology

The meteorology data for Sacramento and Los Angeles were provided by ARB from the locations nearest to the Ambient site. In Sacramento, this was the 13th and T street location. In Los Angeles, the site was located at the SCAQMD ambient monitoring site at Pico Rivera. The summarized data included: temperature (°F), relative humidity (%), wind speed (mph), and wind direction (degrees).

3.0 RESULTS

The data presented in this section summarize the pollutant, vehicular, and meteorological measures for all commutes, grouped by scenario. The measurement data for each of the 29 individual commutes are provided in Appendix H (all measures except non-target metals) and Appendix I (non-target metals). These measures are reported as "censored" data with the censor levels determined using either the MDL or MQL, according to the guidelines shown in Appendix J. The composite data tables in Section 3.0 and 4.0 (typically means and mean differences) were computed using "uncensored" data. Uncensored data are generally all measurements above the MDL, and ½ the MDL if below this level. Since MDL's were not available for all measures, an exception data treatment table was prepared (included in Appendix J). Note that the Pilot Study data summaries (Appendix A) were computed slightly differently by replacing values below the MQL's with zeros.

3.1 Percent Measurable Data and Data Capture Rates

The percentage of samples above the reporting level (MQL) was significantly influenced by the desire to make pollutant measurements over very short time periods. While the "clean" ambient conditions in the Pilot Study posed substantial analytical difficulties, the higher background ambient levels in Sacramento during the Main Study significantly improved the percentages of data above the MQL's (see Table 3-1A and B). The ambient and in-vehicle pollutant levels in Los Angeles were generally 2-3 times higher than those in Sacramento, greatly reducing the uncertainties associated with measurements near the detection limits.

TABLE 3-1A. Percentage of Integrated Samples Above the Reporting Levels

Analyte	% Above Reporting Level SAC	LA	Reporting Level
Isobutylene	99	100	MQL
1,3-Butadiene	67	97	MQL
Acetonitrile	96	100	MQL
DCM	33	100	MQL
MTBE	92	100	MQL
ETBE	1	0	MQL
Benzene	79	100	MQL
Toluene	99	100	MQL
Ethylbenzene	73	100	MQL
m,p-Xylene	92	100	MQL
o-Xylene	70	100	MQL
TCFM	3	0	MQL
Formaldehyde	96	98	MQL
PM_{10}	64	100	MDL
$PM_{2.5}$	13	97	MDL
CO 1-h average	42	74	MQL
LAS-X Particle Count	100	100	MQL
Black Carbon	100	100	MQL

TABLE 3-1B. Percentage of Integrated Samples Above the Reporting Levels

Analyte	% Above Reporting Level SAC	LA	Reporting Level
$PM_{2.5}$ Pb	1	2	MDL
$PM_{2.5}$ Cd	0	0	MDL
$PM_{2.5}$ Cr	0	0	MDL
$PM_{2.5}$ Mn	0	0	MDL
$PM_{2.5}$ Ni	0	0	MDL
$PM_{2.5}$ S	98	100	MDL
PM_{10} Pb	2	3	MDL
PM_{10} Cd	0	0	MDL
PM_{10} Cr	0	0	MDL
PM_{10} Mn	0	0	MDL
PM_{10} Ni	0	2	MDL
PM_{10} S	100	100	MDL

The percent data capture goals for this program were generally 90% or better. The actual data capture levels for the integrated and continuous measurements shown in Tables 3-2A and 3-2B were excellent. The primary data losses were for the LAS-X and Aethalometer, which lost power several times in Sacramento and Los Angeles due to inverter system power failures in Vehicle 1. Two CO hourly data files were lost (commute #1, OUT 1 and commute #8, OUT 1) in Sacramento during data transfer.

3.2 Quality Assurance Data Summary

3.2.1 General

The quality of data for the project resulted from the uniform application of quality assurance goals in all phases of the project. Careful attention to detail in planning the study operations, combined with capable, well-trained (and dedicated) staff and equipment produced a data base of carefully defined quality, with a minimum of lost data. A preliminary Pilot Study (see Appendix A) to test the measurement methodologies proved invaluable in maximizing the data quality and the percent data capture in the Main Study. The Pilot Study was prompted by the research nature of the project, which required the measurement of pollutant concentrations in a mobile, field setting, over very short time periods.

An internal leak in the calibration standard transfer line, during the GC/MS calibration, resulted in a reporting problem (more than 1 MQL for some of the Sacramento samples), but otherwise the VOC data quality (see Table 2-4 for detailed result) were excellent. The target compound, MTBE, had a nominal MQL of 1.0 $\mu g/m^3$ in Sacramento and Los Angeles with a mean precision from duplicate field samples of only 6 %. The data for formaldehyde were similarly excellent, with an MQL of 3.1 $\mu g/m^3$ and a precision of 5 % in Sacramento and 10 % in Los Angeles.

The $PM_{2.5}$ and PM_{10} integrated mass concentrations exhibited relatively high MQL's, as a result of the extremely short sample times and minimal air volume collected (0.48 m^3). The field weighing performance was excellent for such small mass collections, resulting in acceptable precisions for $PM_{2.5}$ in both Sacramento (10.3 %) and Los Angeles (8.5 %). The very low percent data capture rates for all of the target elements, except sulfur, were expected, based on preliminary elemental data from the Pilot Study. While more sensitive analysis by ICP/MS may have been desirable, the much higher cost was beyond the resources of this project. Definition of the MDL values for the target elements by XRF, provided the ability to provide these limits in the data.

The mobile sampling platform designed to accommodate to continuous particle monitors (LAS-X and Aethalometer), normally used as laboratory tools, proved challenging. Except for in-vehicle power problems, however, the units functioned according to the manufacturers specifications.

3.2.2 Summary of Key Method Quality Measures

The MDL's (if applicable), MQL's, and replicate measure precisions, expressed as percent coefficients of variation, are tabulated in Table 3-3A thru D for Sacramento and Los Angeles. The MDL's and MQL's are the lowest levels reported for the individual sample data. The precision data were determined for collocated samples exceeding the MQL. Since none of

the $PM_{2.5}$ collocated sample pairs in Sacramento exceeded the MQL of 19.7 $\mu g/m^3$, an estimated precision based on the replicates above the MDL is provided. Note that all of the precisions for data above the MQL are excellent and met study QA requirements.

Table 3-2A. ARB In-Vehicle Study Integrated Sample & Data Capture Matrix for Sacramento

Integrated Sample Collection totals for 13 commutes: Planned/Valid												
	Vehicle 1		**Vehicle 2**				Total					
	Inside	**Outside**	**Inside**	**Outside**	**Rdside 1**	**Rdside 2**	**Ambient**	**All**	**Total**	**Total**	**Total**	**Total**
Code>	**IN1**	**OUT1**	**IN2**	**OUT2**	**ROAD1**	**ROAD2**	**AMB**	**Dups**	**Planned**	**Valid**	**Quest.?**	**Invalid**
Sample Type												
Particles, 2.5 µm (gravimetric)	13/13	13/13	13/13	13/13	9/9	9/9	12/12	4/4	86	86	0	0
Particles, 10 µm (gravimetric)	13/13	----	13/13	----	9/9	9/9	12/12	3/3	59	59	0	0
VOC's (canister collection, GC/MS analysis)	13/13	13/13	13/13	13/13	9/9	9/9	12/12	4/4	86	86	0	0
Formaldehyde (DNPH cartridge collection, HPLC analysis)	13/13	----	13/13		9/9	9/9	12/10	5/5	60	58	0	2
Carbon Monoxide (Draeger)	13/13	13/11	13/12	13/13	9/9	9/9	12/12	4/4	87	84		3
Black Carbon (Aethalometer)	13/13	13/13	----	----	----	----	----	----	26	26	0	0
Particle Count Total 0.15 - 2.5 µm (LAS-X)	13/8	13/8	----	----	----	----	----	----	26	16	0	10
Notes:	Field blanks and field controls not included in this table.											
	Carbon monoxide, black carbon, particle count data are means of 120 one-minute values/commute											

Table 3-2B. ARB In-Vehicle Study Integrated Sample & Data Capture Matrix for Los Angeles

Integrated Sample Collection totals for 16 commutes:

	Vehicle 1		Vehicle 2				Total					
	Inside	**Outside**	**Inside**	**Outside**	**Rdside 1**	**Rdside 2**	**Ambient**	**All**	**Total**	**Total**	**Total**	**Total**
Code>	**IN1**	**OUT1**	**IN2**	**OUT2**	**ROAD1**	**ROAD2**	**AMB**	**Dups**	**Planned**	**Valid**	**Quest.?**	**Invalid**
Sample Type												
Particles, 2.5 µm (gravimetric)	16/16	16/16	16/16	16/16	12/12	12/12	16/12	4/4	108	108	0	0
Particles, 10 µm (gravimetric)	16/16	----	16/16	----	12/12	12/12	16/16	3/3	76	76	0	0
VOC's (canister collection, GC/MS analysis)	16/16	16/16	16/16	16/16	12/12	12/12	16/16	4/4	108	108	0	0
Formaldehyde (DNPH cartridge collection, HPLC analysis)	16/15	----	14/14	----	10/10	10/9	16/15	4/4	87	87	0	3
Carbon Monoxide (Draeger)	16/16	16/16	----	----	16	16	16	----	112	112	0	1
Black Carbon (Aethalometer)	16	16	----	----	----	----	----	----	32	32	0	0
Particle Count Total 0.15 - 2.5 µm (LAS-X)	16/16	16/15	----	----	----	----	----	----	111	111	0	1
Notes:	Field blanks and field controls not included in this table.											
	Carbon monoxide, black carbon, particle count data are means of 120 one-minute values/commute											

Table 3-3A. Summary of Key Sacramento Quality Assurance Data

Pollutant/Measure	MDL[a] (measure units)	MQL[b] (measure units)	Duplicate +/- Precision[c] (% CV)
Isobutylene, $\mu g/m^3$	na	0.22 (0.44)	4.5
1,3-Butadiene, $\mu g/m^3$	na	0.30 (0.60)	7.9
Acetonitrile, $\mu g/m^3$	na	0.70 (1.4)	6.6
Dichloromethane [DCM], $\mu g/m^3$	na	1.1 (2.2)	30
Methyl-Tertiary-Butyl-Ether [MTBE], $\mu g/m^3$	na	1.0 (2.0)	6.1
Ethyl-Tertiary-Butyl Ether [ETBE], $\mu g/m^3$	na	1.0 (2.0)	na
Benzene, $\mu g/m^3$	na	1.1 (2.2)	5.5
Toluene, $\mu g/m^3$	na	1.1 (2.2)	8.4
Ethylbenzene, $\mu g/m^3$	na	0.80 (1.6)	3.0
m,p-Xylene, $\mu g/m^3$	na	1.2 (2.4)	3.8
o-Xylene, $\mu g/m^3$	na	1.1 (2.2)	3.3
Trichloro-fluoro-methane [TCFM], $\mu g/m^3$	na	0.37 (0.70)	na
PM_{10}, $\mu g/m^3$	6.6	19.7	10.3
$PM_{2.5}$, $\mu g/m^3$	6.6	19.7	22.0[c]
Formaldehyde, $\mu g/m^3$	na	3.1	5.0
Carbon Monoxide [CO], ppm	na	2	20.5

Table 3-3 A thru D Notes:

[a] MDL's: Measurement Detection Limits not available for VOC's; gravimetric particle mass MDL's determined from replicate filter weighings; XRF elemental MDL's determined from count statistics uncertainties; MDL for CO monitor based on manufacturer's data; LAS-X and Aethalometer MDL's are judgmental estimates

[b] MQL's: Measurement Quantification Limits computed as 3 times MDL's, if MDL is available; MQL's for VOC's are based on lowest calibration point. Values in parentheses are based on the lowest calibration points for some sets of data (see section 2.4.3.2).

[c] Duplicate Precisions: precisions determined from collocated measurements (if available) as pooled means of standard deviations. judgment estimates are made of standard deviations, if collocated measure was not available. $PM_{2.5}$ CV for Sacramento based on replicates above the MDL, since no replicates were measured above the MQL.

Table 3-3B. Summary of Key Sacramento Quality Assurance Data (cont'd)

Pollutant/Measure	MDL[a] (measure units)	MQL[b] (measure units)	Duplicate +/- Precision[c] (% CV)
Particle Count by Size [PMS LAS-X], count 0.15 mm to 2.5 µm	+/- 3 % or 1 particle (higher number	+/- 10 % or 3 particles (higher number	na
Black Carbon [McGee Scientific Aethalometer] µg/m3	0.2 µg/m^3 (est.)	0.6 µg/m^3 (est.)	na
$PM_{2.5}$ Cadmium [Cd], µg/m^3	0.2	na	na
$PM_{2.5}$ Chromium [Cr], µg/m^3	0.8	na	na
$PM_{2.5}$ Manganese [Mn], µg/m^3	0.07	na	na
$PM_{2.5}$ Lead [Pb], µg/m^3	0.06	na	na
$PM_{2.5}$ Nickel [Ni], µg/m^3	0.05	na	na
$PM_{2.5}$ Sulfur [S], µg/m^3	0.08	na	11.6
PM_{10} Cadmium [Cd], µg/m^3	0.2	na	na
PM_{10} Chromium [Cr], µg/m^3	0.8	na	na
PM_{10} Manganese [Mn], µg/m^3	0.07	na	na
PM_{10} Lead [Pb], µg/m^3	0.06	na	na
PM_{10} Nickel [Ni], µg/m^3	0.05	na	na
PM_{10} Sulfur [S], µg/m^3	0.08	na	6.6
Air Exchange Rate [Constant Speed], /hr	na	na	10.2
Vehicle Speed, mph	0.4 mph	0.8 mph	na
Vehicle Spacing, feet	0.5 feet	1.5 feet	na
Level of Congestion, unitless	na	na	na

Table notes following Table 3-3 A apply

Table 3-3C. Summary of Key Los Angeles Quality Assurance Data

Pollutant/Measure	MDL[a] (measure units)	MQL[b] (measure units)	Duplicate +/- Precision[c] (% CV)
Isobutylene, $\mu g/m^3$	na	0.22	6.3
1,3-Butadiene, $\mu g/m^3$	na	0.30	6.9
Acetonitrile, $\mu g/m^3$	na	0.70	12
Dichloromethane [DCM], $\mu g/m^3$	na	1.1	9.3
Methyl-Tertiary-Butyl-Ether [MTBE], $\mu g/m^3$	na	1.0	6.5
Ethyl-Tertiary-Butyl Ether [ETBE], $\mu g/m^3$	na	1.0	na
Benzene, $\mu g/m^3$	na	1.1	4.9
Toluene, $\mu g/m^3$	na	1.1	4.5
Ethylbenzene, $\mu g/m^3$	na	0.80	3.1
m,p-Xylene, $\mu g/m^3$	na	1.2	4.1
o-Xylene, $\mu g/m^3$	na	1.1	3.4
Trichloro-fluoro-methane [TCFM], $\mu g/m^3$	na	0.37	na
PM_{10}, $\mu g/m^3$	4.3	13.0	4.0
$PM_{2.5}$, $\mu g/m^3$	4.3	13.0	8.5
Formaldehyde, $\mu g/m^3$	na	3.1	9.6
Carbon Monoxide [CO], ppm	na	2.0	10.2

Table notes following Table 3-3 A apply

Table 3-3D. Summary of Key Los Angeles Quality Assurance Data (cont'd)

Pollutant/Measure	MDL[a] (measure units)	MQL[b] (measure units)	Duplicate +/- Precision[c] (% CV)
Particle Count by Size [PMS LAS-X], count 0.15 mm to 2.5 mm	+/- 3 % or 1 particle (whichever is higher)	+/- 10 % or 3 particles (whichever is higher)	na
Black Carbon [McGee Scientific Aethalometer] µg/m3	0.2 mg/m^3 (est.)	0.6 mg/m^3 (est.)	na
$PM_{2.5}$ Cadmium [Cd], µg/m^3	0.2	na	na
$PM_{2.5}$ Chromium [Cr], µg/m^3	0.8	na	na
$PM_{2.5}$ Manganese [Mn], µg/m^3	0.07	na	na
$PM_{2.5}$ Lead [Pb], µg/m^3	0.06	na	na
$PM_{2.5}$ Nickel [Ni], µg/m^3	0.05	na	na
$PM_{2.5}$ Sulfur [S], µg/m^3	0.08	na	4.7
PM_{10} Cadmium [Cd], µg/m^3	0.2	na	na
PM_{10} Chromium [Cr], µg/m^3	0.8	na	na
PM_{10} Manganese [Mn], µg/m^3	0.07	na	na
PM_{10} Lead [Pb], µg/m^3	0.06	na	na
PM_{10} Nickel [Ni], µg/m^3	0.05	na	na
PM_{10} Sulfur [S], µg/m^3	0.08	na	2.0
Air Exchange Rate [Constant Speed], /hr	na	na	10.2
Vehicle Speed, mph	0.4 mph	0.8 mph	na
Vehicle Spacing, feet	0.5 feet	1.5 feet	na
Level of Congestion, unitless	na	na	na

Table notes following Table 3-3 A apply

3.3 Pollutant Data Summaries

3.3.1 General Organization

The concentration mean data for all pollutant measures is summarized by commute scenario (type) for Sacramento in Tables 3-4A thru 3-4F, and for Los Angeles in Tables 3-5A thru 3-5F. These tables are organized generally by pollutant category and measurement type, by commutes for each city, and provide means and ranges of pollutant concentrations for the following locations:

Ambient site (**AMB**),
Inside vehicles 1 and 2 (**IN 1** and **IN 2**),
Outside vehicles 1 and 2 (**OUT 1** and **OUT 2**), and at the
Roadside sites (**ROAD 1** and **ROAD 2**).

The commute scenario codes are:

Arterial Rush (**AR**),
Arterial Non-Rush (**ANR**),
Freeway Rush (**FR**),
Freeway Non-Rush (**FNR**),
Rural (**R**),
School Bus (**SB**),
Freeway Rush Carpool (**FRC**), and
Maximum Commute (**MC**).

Not all measurements were made at each location and commute type (e.g. PM_{10} was not determined immediately outside any vehicle; formaldehyde samples were collected at only a subset of locations), resulting in **na** (not available) entries. A list of individual pollutant measures for all 29 commutes is given in Appendix H (except for the non-target elements by XRF). Tables 3-4E and 3-5E summarize the associated vehicular characterization measurements made in Vehicle 1 in Sacramento and LA, while the meteorology data collected for both cities at the ambient site, in given in Tables 3-4F and 3-5F, respectively. Note that wind direction (a vector quantity) is not summarized here, but is discussed subsequently in Section 3.5. More detailed data analysis and inter-comparisons between commute types, vehicle, etc. are addressed in the discussion Section 4, which evaluate the research design objectives proposed in Table 1-2. The non-target elements for each commute for $PM_{2.5}$ and PM_{10} are provided in Appendix I.

Table 3-4A. Summary of Organic Pollutant Commute-Average Concentration Data for Sacramento

		Concentrations in Measure units								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Isobutylene	AR	2.7	11.6	10.5 - 14.1	10.4	9.5	8.4 - 10.5	9.2	5.1	3.3 - 6.5
µg/m3	FNR	1.2	6.0	5.3 - 6.6	5.7	5.0	4.5 - 5.5	4.6	1.5	1.1 - 2.1
	FR	1.9	10.4	6.8 - 14.1	10.3	12.4	8.7 - 17.7	9.7	3.2	1.6 - 6.2
	R	na	3.6	3.6 - 3.6	1.7	1.1	1.1 - 1.1	1.3	0.8	0.7 - 0.9
	SB	1.2	3.2	3.1 - 3.3	2.8	2.2	1.4 - 3.1	2.2	na	na - na
1,3-Butadiene	AR	0.5	2.8	2.4 - 3.5	2.4	1.7	1.6 - 1.9	2.0	1.0	0.7 - 1.1
µg/m3	FNR	0.1	1.9	1.6 - 2.2	1.3	1.4	1.3 - 1.5	1.3	0.2	0.1 - 0.2
	FR	0.1	2.7	1.6 - 4.1	2.8	2.8	1.7 - 4.4	2.3	0.4	0.0 - 1.1
	R	na	0.6	0.6 - 0.6	0.3	0.2	0.2 - 0.2	0.2	0.2	0.2 - 0.2
	SB	0.2	0.7	0.6 - 0.7	0.5	0.5	0.3 - 0.8	0.5	na	na - na
Acetonitrile	AR	36.7	174.1	53 - 345	2.0	170.2	52 - 456	94.3	39.4	10 - 109
µg/m3	FNR	22.5	44.7	27 - 62	2.0	40.4	37 - 44	44.0	53.7	10 - 101
	FR	45.3	116.7	18 - 279	1.8	222.5	42 - 627	107.8	48.8	4 - 93
	R	na	29.8	30 - 30	3.0	39.9	40 - 40	12.4	2.8	2 - 3
	SB	66.7	34.1	30 - 38	2.6	17.6	10 - 25	29.0	na	na - na
DCM	AR	4.1	2.2	1.1 - 3.7	1.6	1.6	1.1 - 2.0	2.5	4.1	2.7 - 5.5
µg/m3	FNR	1.1	0.9	0.9 - 0.9	1.1	0.8	0.6 - 1.0	1.2	1.2	0.5 - 2.3
	FR	1.9	0.9	0.5 - 1.3	1.1	1.6	0.5 - 3.4	1.9	1.7	0.5 - 4.4
	R	na	1.4	1.4 - 1.4	0.7	2.6	2.6 - 2.6	1.4	2.6	2.4 - 2.8
	SB	5.1	1.0	0.3 - 1.6	1.1	0.9	0.4 - 1.5	1.6	na	na - na
MTBE	AR	6.7	30.3	25.9 - 36.3	26.5	22.0	18.9 - 24.3	20.7	11.2	8.5 - 14.1
µg/m3	FNR	2.0	10.6	9.3 - 12.0	13.3	11.4	7.5 - 15.3	11.7	2.9	1.1 - 3.9
	FR	3.2	23.0	16.3 - 29.4	21.2	20.9	10.9 - 26.8	18.6	6.5	1.7 - 11.8
	R	na	2.6	2.6 - 2.6	2.2	1.4	1.4 - 1.4	1.4	1.1	1.1 - 1.2
	SB	2.2	7.3	6.0 - 8.7	6.2	5.2	3.1 - 7.4	4.7	na	na - na
ETBE	AR	0.8	0.3	0.0 - 0.4	0.4	0.4	0.3 - 0.4	0.9	0.9	0.2 - 1.6
µg/m3	FNR	0.0	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.1
	FR	0.1	0.0	0.0 - 0.1	0.0	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.2
	R	na	0.1	0.1 - 0.1	0.0	0.1	0.1 - 0.1	0.2	0.6	0.5 - 0.7
	SB	0.2	0.0	0.0 - 0.0	0.1	0.1	0.0 - 0.2	0.1	na	na - na
TCFM	AR	4.2	8.9	2.9 - 24.6	3.1	3.0	2.8 - 3.1	4.7	4.3	2.1 - 6.7
µg/m3	FNR	1.8	1.6	1.6 - 1.7	1.7	1.5	1.4 - 1.6	1.6	1.7	1.5 - 1.8
	FR	2.2	2.4	1.6 - 3.0	2.3	3.0	2.1 - 5.0	2.8	2.2	1.8 - 2.6
	R	na	2.2	2.2 - 2.2	1.9	2.2	2.2 - 2.2	2.2	3.0	2.8 - 3.2
	SB	2.1	1.6	1.3 - 1.9	1.8	1.6	1.3 - 1.9	1.6	na	na - na
Benzene	AR	2.9	12.1	10.2 - 15.2	10.0	11.2	9.4 - 13.9	10.9	5.0	4.2 - 5.9
µg/m3	FNR	0.9	6.5	5.7 - 7.4	6.5	7.2	6.9 - 7.6	7.2	1.0	0.6 - 1.4
	FR	1.4	10.3	7.4 - 13.9	11.2	13.9	11.7 - 15.9	12.3	2.6	0.8 - 5.3
	R	na	3.1	3.1 - 3.1	1.6	2.0	2.0 - 2.0	1.7	1.0	0.9 - 1.1
	SB	1.1	3.5	3.2 - 3.7	2.8	2.5	1.4 - 3.6	2.2	na	na - na
Toluene	AR	8.2	35.4	26.3 - 45.9	25.5	24.4	19.8 - 27.7	23.3	12.3	9.4 - 14.8
µg/m3	FNR	5.8	13.1	9.3 - 17.0	14.1	15.3	14.8 - 15.7	18.3	6.2	3.7 - 9.3
	FR	4.6	32.0	23.7 - 38.4	24.1	27.6	20.2 - 35.8	25.2	7.3	3.1 - 10.6
	R	na	7.4	7.4 - 7.4	4.1	3.2	3.2 - 3.2	3.0	2.2	2.1 - 2.2
	SB	3.7	12.2	11.0 - 13.3	8.0	6.0	3.8 - 8.1	6.0	na	na - na
Ethylbenzene	AR	1.8	8.2	6.4 - 10.1	6.4	5.7	4.8 - 6.2	5.7	3.0	2.5 - 3.3
µg/m3	FNR	3.2	2.9	2.8 - 3.0	2.5	2.5	2.4 - 2.5	2.4	0.7	0.3 - 0.9
	FR	0.7	5.5	3.7 - 7.1	4.5	5.0	3.8 - 6.0	4.4	1.2	0.3 - 2.2
	R	na	1.6	1.6 - 1.6	0.8	0.6	0.6 - 0.6	0.6	0.6	0.5 - 0.7
	SB	0.6	2.5	2.3 - 2.8	1.7	1.3	0.7 - 1.9	1.2	na	na - na
M,P-Xylene	AR	5.0	31.0	22.9 - 38.2	22.7	19.8	16.7 - 22.1	19.3	8.9	6.5 - 10.9
µg/m3	FNR	1.8	12.6	12.5 - 12.7	10.8	11.0	11.0 - 11.1	10.8	2.6	1.3 - 3.5
	FR	2.7	24.7	17.0 - 30.1	19.4	21.1	16.9 - 26.7	18.8	4.9	1.4 - 8.0
	R	na	5.3	5.3 - 5.3	2.6	1.8	1.8 - 1.8	1.6	1.2	1.1 - 1.3
	SB	1.8	8.9	7.8 - 9.9	5.8	4.3	2.4 - 6.1	3.9	na	na - na
O-Xylene	AR	2.3	10.7	8.3 - 13.0	8.3	7.1	5.9 - 7.8	7.4	3.6	3.2 - 3.8
µg/m3	FNR	0.7	4.4	4.4 - 4.5	3.8	3.9	3.8 - 4.0	3.7	1.0	0.6 - 1.3
	FR	1.5	8.4	5.9 - 9.8	6.7	7.2	6.0 - 9.0	6.6	2.2	0.6 - 3.6
	R	na	2.0	2.0 - 2.0	1.0	0.7	0.7 - 0.7	0.7	0.8	0.7 - 0.8
	SB	0.8	3.2	2.8 - 3.7	2.2	1.7	0.9 - 2.4	1.5	na	na - na
Formaldehyde	AR	4.1	11.9	10.2 - 13.9	NA	11.9	8.8 - 18.5	na	6.3	5.2 - 7.4
µg/m3	FNR	2.0	8.0	7.7 - 8.4	NA	7.9	7.5 - 8.4	na	5.2	4.9 - 5.7
	FR	3.0	11.9	11.3 - 12.3	NA	12.4	9.3 - 17.4	na	5.4	3.0 - 8.3
	R	na	4.9	4.9 - 4.9	NA	5.8	5.8 - 5.8	na	4.6	4.3 - 5.0
	SB	2.8	7.0	4.6 - 9.5	NA	8.6	6.4 - 10.9	na	na	na - na

See table notes following Table 3-4B

Table 3-4B. Summary of Continuous Pollutant Commute-Average Concentration Data for Sacramento

		Concentrations in Measure units								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
CO Average	AR	0.0	2.3	2.0 - 2.6	2.8	3.0	2.1 - 5.1	4.1	0.4	0.2 - 0.7
ppm	FNR	0.0	1.4	1.2 - 1.7	2.2	3.5	2.8 - 4.2	3.9	0.0	0.0 - 0.1
	FR	0.0	2.1	1.8 - 2.3	2.2	3.1	2.6 - 4.1	4.2	0.3	0.0 - 1.2
	R	na	0.7	0.7 - 0.7	0.2	0.4	0.4 - 0.4	0.6	0.0	0.0 - 0.0
	SB	0.0	0.4	0.3 - 0.5	0.3	0.3	0.3 - 0.3	0.3	na	0.0 - 0.0
CO Peak	AR	0.8	10.8	8.0 - 16.0	23.7	9.5	4.0 - 14.0	13.5	4.5	2.0 - 8.0
ppm	FNR	0.0	13.0	7.0 - 19.0	14.0	12.5	10.0 - 15.0	13.0	0.5	0.0 - 1.0
	FR	0.0	10.5	3.0 - 17.0	11.5	22.3	7.0 - 52.0	25.8	2.0	0.0 - 4.0
	R	na	22.0	22.0 - 22.0	8.0	6.0	6.0 - 6.0	11.0	0.5	0.0 - 1.0
	SB	0.0	2.5	2.0 - 3.0	2.5	3.0	3.0 - 3.0	2.5	na	0.0 - 0.0
Black Carbon	AR	na	1.2	-0.1 - 3.3	3.1	na	na - na	na	na	na - na
Aethalometer	FNR	na	8.3	7.6 - 9.0	4.0	na	na - na	na	na	na - na
µg/m3	FR	na	6.7	3.3 - 9.5	7.9	na	na - na	na	na	na - na
	R	na	-0.3	-0.3 - -0.3	1.4	na	na - na	na	na	na - na
	SB	na	4.9	0.9 - 8.9	7.0	na	na - na	na	na	na - na
LASX	AR	na	33	33 - 33	139	na	na - na	na	na	na - na
mean total	FNR	na	991	818 - 1,164	1,857	na	na - na	na	na	na - na
particle	FR	na	759	542 - 976	1,942	na	na - na	na	na	na - na
counts/cm3	R	na	10	10 - 10	32	na	na - na	na	na	na - na
	SB	na	24	18 - 29	96	na	na - na	na	na	na - na

Notes: a Expected n values by Sacramento commute scenario Type are: AR (4), FNR(2), FR(4), R(1), and SB(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

Ambient data not available to correct black carbon or LAS-X data

LAS-X OUT data corrected for sampling line losses

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-4C. Summary of PM10 Pollutant Commute-Average Concentration Data for Sacramento

		Concentrations in Measure units								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
PM 10 mass	AR	20.3	16.5	14.1 - 20.7	na	10.7	6.3 - 16.5	na	30.9	18.9 - 43.0
µg/m3	FNR	29.4	29.6	28.7 - 30.6	na	13.4	8.4 - 18.3	na	34.4	23.7 - 57.7
	FR	22.7	30.3	19.9 - 39.4	na	10.0	2.1 - 17.9	na	27.3	10.2 - 42.5
	R	na	26.2	26.2 - 26.2	na	14.0	14.0 - 14.0	na	57.2	29.8 - 84.6
	SB	29.5	26.2	20.4 - 31.9	na	32.1	20.7 - 43.4	na	NA	0.0 - 0.0
PM10 Cr	AR	0.02	0.01	0.00 - 0.03	na	0.02	0.00 - 0.05	na	0.00	0.00 - 0.01
µg/m3	FNR	0.02	0.03	0.03 - 0.03	na	0.00	0.00 - 0.00	na	0.03	0.01 - 0.06
	FR	0.03	0.03	0.00 - 0.05	na	0.02	0.00 - 0.04	na	0.02	0.00 - 0.04
	R	na	0.05	0.05 - 0.05	na	0.00	0.00 - 0.00	na	0.03	0.01 - 0.04
	SB	0.01	0.01	0.01 - 0.01	na	0.04	0.01 - 0.06	na	NA	0.00 - 0.00
PM10 Mn	AR	0.02	0.03	0.00 - 0.07	na	0.01	0.00 - 0.02	na	0.03	0.00 - 0.05
µg/m3	FNR	0.03	0.01	0.00 - 0.02	na	0.02	0.00 - 0.03	na	0.02	0.01 - 0.05
	FR	0.02	0.03	0.01 - 0.05	na	0.02	0.00 - 0.03	na	0.04	0.00 - 0.06
	R	na	0.00	0.00 - 0.00	na	0.00	0.00 - 0.00	na	0.02	0.01 - 0.04
	SB	0.04	0.01	0.00 - 0.02	na	0.03	0.00 - 0.06	na	NA	0.00 - 0.00
PM10 Ni	AR	0.01	0.01	0.01 - 0.02	na	0.01	0.00 - 0.02	na	0.00	0.00 - 0.01
µg/m3	FNR	0.01	0.01	0.00 - 0.02	na	0.00	0.00 - 0.00	na	0.00	0.00 - 0.02
	FR	0.00	0.00	0.00 - 0.00	na	0.01	0.00 - 0.03	na	0.00	0.00 - 0.01
	R	na	0.01	0.01 - 0.01	na	0.01	0.01 - 0.01	na	0.01	0.01 - 0.02
	SB	0.01	0.00	0.00 - 0.01	na	0.02	0.02 - 0.03	na	NA	0.00 - 0.00
PM10 Pb	AR	0.02	0.04	0.02 - 0.08	na	0.01	0.00 - 0.04	na	0.03	0.00 - 0.06
µg/m3	FNR	0.01	0.02	0.01 - 0.02	na	0.01	0.00 - 0.02	na	0.00	0.00 - 0.01
	FR	0.01	0.02	0.00 - 0.03	na	0.01	0.00 - 0.05	na	0.02	0.00 - 0.04
	R	na	0.02	0.02 - 0.02	na	0.00	0.00 - 0.00	na	0.02	0.00 - 0.04
	SB	0.00	0.01	0.00 - 0.02	na	0.01	0.00 - 0.03	na	NA	0.00 - 0.00
PM10 S	AR	0.44	0.37	0.09 - 0.74	na	0.28	0.13 - 0.55	na	0.64	0.45 - 0.84
µg/m3	FNR	0.68	0.61	0.42 - 0.80	na	0.48	0.27 - 0.70	na	0.73	0.43 - 1.12
	FR	0.48	0.47	0.21 - 0.88	na	0.30	0.16 - 0.59	na	0.53	0.24 - 1.04
	R	na	0.29	0.29 - 0.29	na	0.24	0.24 - 0.24	na	0.35	0.30 - 0.39
	SB	0.26	0.29	0.24 - 0.33	na	0.22	0.16 - 0.28	na	NA	0.00 - 0.00

Notes: a Expected n values by Sacramento commute scenario Type are: AR (4), FNR(2), FR(4), R(1), and SB(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-4D. Summary of PM2.5 Pollutant Commute-Average Concentration Data for Sacramento

		Concentrations in Measure units								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
PM 2.5 mass	AR	10.8	9.6	8.0 - 10.3	17.4	9.7	2.1 - 16.4	12.7	5.8	-2.1 - 18.7
µg/m3	FNR	10.3	14.4	12.2 - 16.6	23.0	12.4	10.6 - 14.2	15.4	9.6	0.0 - 19.9
	FR	5.7	14.7	3.9 - 21.8	20.5	6.6	2.1 - 16.2	12.2	5.9	-6.1 - 18.2
	R	na	6.1	6.1 - 6.1	2.0	2.0	2.0 - 2.0	9.8	3.1	1.9 - 4.2
	SB	6.2	17.0	12.0 - 22.0	13.5	19.8	16.9 - 22.8	16.2	na	na - na
PM2.5 Cd	AR	0.04	0.04	0.00 - 0.10	0.04	0.07	0.00 - 0.17	0.03	0.06	0.00 - 0.16
µg/m3	FNR	0.05	0.01	0.00 - 0.03	0.01	0.07	0.04 - 0.10	0.04	0.04	0.00 - 0.09
	FR	0.02	0.08	0.00 - 0.14	0.05	0.05	0.00 - 0.12	0.01	0.04	0.00 - 0.16
	R	na	0.02	0.02 - 0.02	0.02	0.00	0.00 - 0.00	0.00	0.03	0.00 - 0.07
	SB	0.09	0.06	0.06 - 0.07	0.15	0.01	0.00 - 0.01	0.00	na	na - na
PM2.5 Cr	AR	0.01	0.01	0.00 - 0.03	0.01	0.01	0.00 - 0.03	0.03	0.03	0.01 - 0.05
µg/m3	FNR	0.00	0.02	0.02 - 0.03	0.03	0.04	0.04 - 0.04	0.00	0.01	0.00 - 0.03
	FR	0.02	0.01	0.00 - 0.03	0.01	0.02	0.00 - 0.04	0.01	0.02	0.00 - 0.04
	R	na	0.04	0.04 - 0.04	0.03	0.02	0.02 - 0.02	0.00	0.01	0.01 - 0.01
	SB	0.03	0.03	0.00 - 0.05	0.00	0.00	0.00 - 0.00	0.01	na	na - na
PM2.5 Mn	AR	0.01	0.02	0.00 - 0.04	0.01	0.01	0.00 - 0.02	0.02	0.01	0.00 - 0.03
µg/m3	FNR	0.03	0.02	0.00 - 0.03	0.03	0.01	0.00 - 0.01	0.01	0.02	0.01 - 0.02
	FR	0.00	0.01	0.00 - 0.04	0.01	0.03	0.01 - 0.05	0.01	0.01	0.00 - 0.03
	R	na	0.02	0.02 - 0.02	0.00	0.00	0.00 - 0.00	0.00	0.02	0.01 - 0.04
	SB	0.01	0.01	0.00 - 0.02	0.01	0.02	0.00 - 0.04	0.00	na	na - na
PM2.5 Ni	AR	0.00	0.00	0.00 - 0.01	0.01	0.01	0.00 - 0.02	0.01	0.00	0.00 - 0.02
µg/m3	FNR	0.01	0.01	0.01 - 0.02	0.01	0.00	0.00 - 0.00	0.01	0.00	0.00 - 0.01
	FR	0.00	0.01	0.00 - 0.03	0.01	0.00	0.00 - 0.00	0.00	0.00	0.00 - 0.02
	R	na	0.03	0.03 - 0.03	0.01	0.00	0.00 - 0.00	0.00	0.00	0.00 - 0.00
	SB	0.01	0.00	0.00 - 0.00	0.01	0.01	0.00 - 0.01	0.01	na	na - na
PM2.5 Pb	AR	0.02	0.02	0.00 - 0.05	0.03	0.01	0.00 - 0.04	0.02	0.01	0.00 - 0.03
µg/m3	FNR	0.02	0.04	0.03 - 0.04	0.02	0.02	0.00 - 0.03	0.03	0.01	0.00 - 0.01
	FR	0.01	0.02	0.01 - 0.05	0.03	0.02	0.02 - 0.03	0.01	0.02	0.00 - 0.04
	R	na	0.00	0.00 - 0.00	0.00	0.01	0.01 - 0.01	0.01	0.02	0.02 - 0.03
	SB	0.01	0.00	0.00 - 0.00	0.01	0.01	0.00 - 0.02	0.01	na	na - na
PM2.5 S	AR	0.39	0.33	0.09 - 0.61	0.40	0.21	0.08 - 0.39	0.27	0.42	0.12 - 0.68
µg/m3	FNR	0.59	0.67	0.46 - 0.88	0.67	0.52	0.46 - 0.58	0.65	0.59	0.39 - 0.80
	FR	0.40	0.42	0.14 - 0.83	0.46	0.29	0.09 - 0.68	0.41	0.43	0.16 - 0.81
	R	na	0.23	0.23 - 0.23	0.23	0.10	0.10 - 0.10	0.29	0.24	0.19 - 0.29
	SB	0.23	0.24	0.24 - 0.24	0.15	0.21	0.21 - 0.22	0.18	na	na - na

Notes: a Expected n values by Sacramento commute scenario Type are: AR (4), FNR(2), FR(4), R(1), and SB(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

MDL's for PM2.5 elements found in Table 3-3B

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-4E. Summary of Associated Commute-Average Measurement Data for Sacramento

		Other Measures in specified units								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Vehicle Speed (mph)	AR	na	23.8	22.2 - 25.1	na	na	na - na	na	na	na - na
	FNR	na	48.6	47.0 - 50.2	na	na	na - na	na	na	na - na
	FR	na	32.5	23.4 - 44.0	na	na	na - na	na	na	na - na
	R	na	53.2	53.2 - 53.2	na	na	na - na	na	na	na - na
	SB	na	14.0	13.3 - 14.6	na	na	na - na	na	na	na - na
Spacing Range (feet)	AR	na	74.4	52.6 - 91.8	na	na	na - na	na	na	na - na
	FNR	na	90.4	83.7 - 97.0	na	na	na - na	na	na	na - na
	FR	na	68.9	56.2 - 79.1	na	na	na - na	na	na	na - na
	R	na	122.1	122.1 - 122.1	na	na	na - na	na	na	na - na
	SB	na	103.6	78.1 - 129.1	na	na	na - na	na	na	na - na
Level of Congestion (unitless)	AR	na	2.5	1.0 - 3.8	na	na	na - na	na	na	na - na
	FNR	na	2.5	2.5 - 2.6	na	na	na - na	na	na	na - na
	FR	na	3.9	2.8 - 5.2	na	na	na - na	na	na	na - na
	R	na	1.0	1.0 - 1.0	na	na	na - na	na	na	na - na
	SB	na	1.4	1.0 - 1.7	na	na	na - na	na	na	na - na
Miles Traveled	AR	na	49.1	45.8 - 52.1	na	na	na - na	na	na	na - na
	FNR	na	99.1	94.0 - 104.2	na	na	na - na	na	na	na - na
	FR	na	68.3	53.9 - 88.5	na	na	na - na	na	na	na - na
	R	na	152.0	152.0 - 152.0	na	na	na - na	na	na	na - na
	SB	na	0.0	0.0 - 0.0	na	na	na - na	na	na	na - na
Heavy Duty Diesel Bus Influence (% of commute)	AR	na	4%	0% - 14%	na	na	na - na	na	na	na - na
	FNR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FR	na	22%	0% - 89%	na	na	na - na	na	na	na - na
	R	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	SB	na	0%	0% - 0%	na	na	na - na	na	na	na - na
Heavy Duty Diesel Truck Influence (% of commute)	AR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FNR	na	66%	50% - 83%	na	na	na - na	na	na	na - na
	FR	na	47%	13% - 90%	na	na	na - na	na	na	na - na
	R	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	SB	na	0%	0% - 0%	na	na	na - na	na	na	na - na
Diesel Influence (other types) (% of commute)	AR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FNR	na	18%	0% - 36%	na	na	na - na	na	na	na - na
	FR	na	7%	0% - 25%	na	na	na - na	na	na	na - na
	R	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	SB	na	50%	0% - 99%	na	na	na - na	na	na	na - na

Notes: a Expected n values by Sacramento commute scenario Type are: AR (4), FNR(2), FR(4), R(1), and SB(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-4F. Summary of Commute-Average Meteorological Data for Sacramento (Ambient Site Only)

Measure	Type	AMB Mean	IN 1 Mean	AMB Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Windspeed	AR	4.8	na	4.8 - 4.8	na	na	na - na	na	na	na - na
(mph)	FNR	6.3	na	6.0 - 6.5	na	na	na - na	na	na	na - na
	FR	3.6	na	3.5 - 3.8	na	na	na - na	na	na	na - na
	R	na	na	NA - NA	na	na	na - na	na	na	na - na
	SB	2.8	na	2.5 - 3.0	na	na	na - na	na	na	na - na
Ambient	AR	72.1	na	71.6 - 72.5	na	na	na - na	na	na	na - na
Temperature	FNR	82.4	na	82.4 - 82.4	na	na	na - na	na	na	na - na
(deg F)	FR	73.9	na	73.4 - 74.3	na	na	na - na	na	na	na - na
	R	na	na	na - na	na	na	na - na	na	na	na - na
	SB	71.2	na	70.7 - 71.6	na	na	na - na	na	na	na - na
Relative	AR	58.8	na	30.0 - 85.0	na	na	na - na	na	na	na - na
Humidity	FNR	36.5	na	23.0 - 53.0	na	na	na - na	na	na	na - na
(%)	FR	55.3	na	24.0 - 83.0	na	na	na - na	na	na	na - na
	R	29.0	na	29.0 - 29.0	na	na	na - na	na	na	na - na
	SB	65.0	na	36.0 - 94.0	na	na	na - na	na	na	na - na
Predominant	AR	none	na	na - na	na	na	na - na	na	na	na - na
Wind	FNR	209	na	na - na	na	na	na - na	na	na	na - na
Direction	FR	none	na	na - na	na	na	na - na	na	na	na - na
(degrees)	R	na	na	na - na	na	na	na - na	na	na	na - na
	SB	323	na	na - na	na	na	na - na	na	na	na - na

Notes: a Expected n values by Sacramento commute scenario Type are: AR (4), FNR(2), FR(4), R(1), and SB(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5A1. Summary of Organic Pollutant Commute-Average Concentration Data for Los Angeles (p.1)

Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Isobutylene µg/m3	ANR	5.8	21.5	19.5 - 23.5	21.7	18.0	17.1 - 19.0	17.4	na	0.0 - 0.0
	AR	4.3	17.6	13.1 - 23.3	17.2	16.6	13.5 - 20.5	15.8	7.1	3.2 - 10.4
	FNR	5.8	17.3	15.3 - 19.2	17.8	14.7	13.4 - 16.0	17.1	na	0.0 - 0.0
	FR	5.2	16.5	11.6 - 25.0	17.7	17.7	14.1 - 25.0	17.3	13.7	6.0 - 22.7
	FRC	3.8	14.2	12.1 - 16.4	14.2	19.4	18.5 - 20.3	20.1	13.0	10.9 - 14.6
	MC	4.3	21.5	19.1 - 23.9	19.6	na	na - na	na	na	na - na
1,3-Butadiene µg/m3	ANR	0.5	3.5	3.4 - 3.7	3.5	2.4	2.3 - 2.4	2.3	na	0.0 - 0.0
	AR	0.4	3.4	2.1 - 4.5	3.4	2.7	2.1 - 3.5	2.7	1.0	0.4 - 1.7
	FNR	0.4	4.1	4.1 - 4.1	4.0	3.2	3.1 - 3.4	3.6	na	0.0 - 0.0
	FR	0.7	3.8	2.8 - 5.7	4.1	3.7	2.6 - 5.1	3.7	2.9	1.2 - 4.9
	FRC	0.4	3.0	2.2 - 3.8	2.9	4.0	3.7 - 4.4	3.9	2.6	2.1 - 3.3
	MC	0.4	4.7	4.4 - 5.0	4.4	na	na - na	na	na	na - na
Acetonitrile µg/m3	ANR	8.4	63.9	27.7 - 100.1	3.1	37.4	24.2 - 50.7	33.9	na	0.0 - 0.0
	AR	30.1	205.1	38.9 - 495.9	2.1	277.4	23.1 - 520.0	168.2	40.5	2.4 - 167.2
	FNR	9.7	25.1	6.3 - 43.9	3.5	46.0	27.8 - 64.1	39.7	na	0.0 - 0.0
	FR	19.9	150.7	42.1 - 375.3	5.7	181.3	39.3 - 374.8	96.8	19.9	3.0 - 111.7
	FRC	76.9	46.2	41.6 - 50.8	2.1	69.1	62.9 - 75.3	48.4	5.7	1.9 - 14.4
	MC	52.8	28.0	27.3 - 28.6	2.4	na	na - na	na	na	na - na
DCM µg/m3	ANR	3.7	2.7	2.1 - 3.3	2.5	2.7	2.5 - 3.0	2.8	na	0.0 - 0.0
	AR	3.6	3.1	2.7 - 3.4	3.1	3.5	2.4 - 5.0	3.2	4.9	2.5 - 13.9
	FNR	16.9	3.5	1.9 - 5.1	3.4	3.7	2.5 - 4.8	3.6	na	0.0 - 0.0
	FR	3.0	2.6	1.2 - 4.3	3.3	3.0	1.5 - 4.6	3.1	2.5	1.4 - 3.9
	FRC	2.4	2.6	1.9 - 3.4	2.5	3.3	3.2 - 3.5	4.0	3.7	1.4 - 7.7
	MC	5.5	4.5	3.7 - 5.4	4.0	na	na - na	na	na	na - na
MTBE µg/m3	ANR	26.3	59.9	41.8 - 78.1	59.2	42.9	33.5 - 52.2	42.8	na	0.0 - 0.0
	AR	9.7	36.0	24.3 - 50.3	36.1	30.6	24.9 - 38.6	29.4	15.0	6.9 - 22.4
	FNR	15.3	41.4	32.1 - 50.7	41.7	34.4	28.1 - 40.7	40.4	na	0.0 - 0.0
	FR	13.5	37.7	19.7 - 64.1	41.5	36.5	28.8 - 54.6	36.3	32.2	15.3 - 58.5
	FRC	10.2	31.2	27.4 - 35.0	31.2	47.0	46.5 - 47.5	47.8	27.6	22.2 - 30.8
	MC	10.7	60.2	30.3 - 90.0	50.9	na	na - na	na	na	na - na
ETBE µg/m3	ANR	0.2	0.0	0.0 - 0.1	0.0	0.1	0.1 - 0.1	0.0	na	0.0 - 0.0
	AR	0.0	0.0	0.0 - 0.1	0.0	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.3
	FNR	0.1	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.0	0.0	na	0.0 - 0.0
	FR	0.1	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.0	0.0	0.1	0.0 - 0.4
	FRC	0.2	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.0	0.0	0.0	0.0 - 0.1
	MC	0.0	0.0	0.0 - 0.0	0.0	na	na - na	na	na	na - na
TCFM µg/m3	ANR	2.0	1.8	1.8 - 1.8	1.8	1.9	1.8 - 2.1	1.8	na	0.0 - 0.0
	AR	1.7	1.5	1.4 - 1.7	1.6	1.6	1.4 - 1.7	1.6	1.7	1.5 - 1.8
	FNR	1.4	1.7	1.6 - 1.7	1.7	1.7	1.7 - 1.7	1.8	na	0.0 - 0.0
	FR	1.8	1.6	0.9 - 2.2	1.9	1.7	1.3 - 2.1	1.7	1.8	1.8 - 2.0
	FRC	1.5	1.5	1.5 - 1.5	1.5	1.5	1.5 - 1.5	1.6	1.8	1.4 - 2.4
	MC	1.7	2.1	1.8 - 2.5	2.0	na	na - na	na	na	na - na
Benzene µg/m3	ANR	6.6	16.7	14.3 - 19.0	16.0	13.9	13.0 - 14.7	13.2	na	0.0 - 0.0
	AR	2.8	14.5	10.2 - 20.7	14.6	12.5	10.5 - 14.9	12.1	5.2	2.3 - 8.5
	FNR	3.9	14.4	13.8 - 15.1	14.5	12.5	12.2 - 12.8	14.0	na	0.0 - 0.0
	FR	4.0	14.4	9.8 - 21.9	15.0	15.5	11.9 - 20.2	15.1	11.8	5.4 - 19.5
	FRC	3.0	12.7	10.6 - 14.8	12.3	17.4	16.1 - 18.6	17.4	11.2	9.2 - 12.5
	MC	2.9	17.2	16.2 - 18.1	15.6	na	na - na	na	na	na - na
Toluene µg/m3	ANR	23.2	44.4	35.0 - 53.9	42.3	32.8	27.5 - 38.2	31.9	na	0.0 - 0.0
	AR	9.6	37.0	28.1 - 49.6	36.0	30.1	26.8 - 34.0	29.7	16.4	6.9 - 27.4
	FNR	39.9	38.8	35.3 - 42.3	39.2	33.0	28.4 - 37.5	38.7	na	0.0 - 0.0
	FR	19.0	34.0	22.6 - 52.4	34.4	31.2	23.7 - 39.7	32.0	43.9	22.5 - 70.5
	FRC	10.3	31.5	26.8 - 36.1	29.8	50.8	44.0 - 57.6	46.3	26.4	21.2 - 28.8
	MC	10.2	37.8	33.6 - 42.0	36.8	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5A2. Summary of Organic Pollutant Commute-Average Concentration Data for Los Angeles (p.2)

Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Ethylbenzene	ANR	3.5	9.7	7.6 - 11.8	9.3	6.5	5.5 - 7.5	6.4	na	0.0 - 0.0
µg/m3	AR	1.6	7.5	5.5 - 10.2	7.1	5.7	5.1 - 6.2	5.7	2.7	1.2 - 4.0
	FNR	2.1	7.3	7.2 - 7.5	7.3	6.1	5.8 - 6.3	6.8	na	0.0 - 0.0
	FR	2.2	7.4	4.7 - 11.5	7.2	6.2	4.5 - 7.7	6.3	5.6	2.7 - 9.7
	FRC	1.7	6.1	4.9 - 7.2	5.6	8.0	8.0 - 8.0	7.6	4.9	3.8 - 5.4
	MC	1.6	8.0	6.7 - 9.3	7.5	na	na - na	na	na	na - na
M,P-Xylene	ANR	9.4	35.5	27.5 - 43.6	33.9	23.7	20.1 - 27.3	22.7	na	0.0 - 0.0
µg/m3	AR	5.3	28.8	19.4 - 40.6	28.6	22.4	19.9 - 24.9	22.3	9.9	4.3 - 14.8
	FNR	5.7	26.9	26.1 - 27.7	26.6	21.5	19.6 - 23.4	24.5	na	0.0 - 0.0
	FR	7.4	28.2	17.3 - 45.4	27.7	23.4	16.7 - 28.9	23.9	20.2	9.0 - 36.9
	FRC	5.2	23.6	18.3 - 28.9	21.9	31.0	30.9 - 31.0	29.3	18.3	13.7 - 20.6
	MC	5.2	32.5	25.6 - 39.5	29.7	na	na - na	na	na	na - na
O-Xylene	ANR	4.0	12.9	9.8 - 15.9	12.7	8.9	7.4 - 10.3	8.3	na	0.0 - 0.0
µg/m3	AR	2.0	10.1	7.1 - 14.1	10.1	8.2	7.2 - 8.9	8.1	3.7	1.6 - 5.6
	FNR	2.5	9.7	9.6 - 9.7	9.5	7.8	7.3 - 8.2	8.9	na	0.0 - 0.0
	FR	2.8	10.0	6.1 - 15.9	9.9	8.5	6.3 - 10.7	8.6	7.5	3.4 - 13.2
	FRC	2.0	8.5	6.7 - 10.3	7.9	11.1	11.1 - 11.2	10.5	6.7	5.1 - 7.6
	MC	2.1	11.5	9.1 - 13.9	10.6	na	na - na	na	na	na - na
Formaldehyde	ANR	19.1	19.7	17.3 - 22.2	na	15.4	7.2 - 23.6	na	na	0.0 - 0.0
µg/m3	AR	7.3	15.5	12.7 - 19.6	na	16.8	11.3 - 22.6	na	11.2	4.4 - 18.8
	FNR	21.1	7.2	0.0 - 14.4	na	13.3	10.4 - 16.2	na	na	0.0 - 0.0
	FR	6.7	16.3	14.7 - 17.0	na	18.0	16.3 - 20.7	na	12.1	0.0 - 16.9
	FRC	8.9	14.0	13.9 - 14.1	na	17.0	15.4 - 18.6	na	15.4	11.0 - 20.3
	MC	10.1	15.6	14.3 - 16.9	na	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5B. Summary of Continuous Commute-Average Pollutant Concentration Data for Los Angeles

		Concentrations								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
CO Average ppm	ANR	0.8	4.2	3.1 - 5.2	4.5	4.6	4.1 - 5.0	5.5	NA	0.0 - 0.0
	AR	0.0	4.2	3.0 - 6.0	4.4	4.4	3.6 - 5.0	4.9	0.6	0.0 - 1.3
	FNR	1.3	4.4	4.1 - 4.6	4.4	4.5	3.9 - 5.0	4.7	NA	0.0 - 0.0
	FR	0.5	5.1	4.0 - 6.0	5.3	5.4	4.4 - 7.6	5.6	3.1	0.7 - 5.2
	FRC	0.0	3.5	2.9 - 4.2	2.8	4.9	4.9 - 4.9	5.6	3.6	2.8 - 4.2
	MC	0.1	4.5	4.4 - 4.6	4.5	na	na - na	na	na	na - na
CO Peak ppm	ANR	2.0	24.0	17.0 - 31.0	28.5	12.5	12.0 - 13.0	17.0	NA	0.0 - 0.0
	AR	0.5	23.3	7.0 - 48.0	40.3	9.0	6.0 - 11.0	14.5	3.5	1.0 - 7.0
	FNR	3.0	26.5	14.0 - 39.0	44.5	17.5	15.0 - 20.0	20.0	NA	0.0 - 0.0
	FR	1.3	34.0	7.0 - 67.0	31.5	12.8	7.0 - 22.0	14.8	6.6	3.0 - 11.0
	FRC	0.0	9.0	6.0 - 12.0	11.0	18.5	15.0 - 22.0	24.0	8.5	7.0 - 10.0
	MC	1.0	25.5	21.0 - 30.0	27.0	na	na - na	na	na	na - na
Black Carbon Aethalometer µg/m3	ANR	NA	15.2	7.6 - 22.9	12.1	na	na - na	na	na	na - na
	AR	NA	7.5	4.1 - 12.9	13.7	na	na - na	na	na	na - na
	FNR	NA	12.1	9.4 - 14.7	16.4	na	na - na	na	na	na - na
	FR	NA	10.4	7.9 - 13.4	17.7	na	na - na	na	na	na - na
	FRC	NA	4.4	3.3 - 5.5	8.4	na	na - na	na	na	na - na
	MC	NA	20.9	20.4 - 21.4	19.9	na	na - na	na	na	na - na
LASX mean total particle counts/cm3	ANR	NA	3,614	2,621 - 4,606	6,033	na	na - na	na	na	na - na
	AR	NA	2,690	2,253 - 2,868	5,170	na	na - na	na	na	na - na
	FNR	NA	4,037	3,733 - 4,341	8,528	na	na - na	na	na	na - na
	FR	NA	2,960	2,258 - 3,606	6,724	na	na - na	na	na	na - na
	FRC	NA	2,817	2,817 - 2,817	5,289	na	na - na	na	na	na - na
	MC	NA	4,325	4,237 - 4,413	7,333	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5C. Summary of PM10 Commute-Average Pollutant Concentration Data for Los Angeles

		Concentrations								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
PM 10 mass	ANR	99.2	69.6	53.7 - 85.5	na	58.4	37.1 - 79.7	na	na	0.0 - 0.0
µg/m3	AR	77.3	45.6	34.6 - 53.1	na	51.4	26.6 - 111.0	na	82.2	31.0 - 166.0
	FNR	53.8	66.6	61.0 - 72.1	na	62.9	58.6 - 67.3	na	NA	0.0 - 0.0
	FR	59.5	54.9	46.0 - 64.8	na	36.2	22.9 - 45.2	na	77.3	43.9 - 129.8
	FRC	102.6	61.1	49.1 - 73.2	na	71.0	67.5 - 74.6	na	122.5	119.2 - 126.1
	MC	56.9	89.1	73.2 - 105.0	na	na	na - na	na	na	na - na
PM10 Cd	ANR	0.03	0.06	0.00 - 0.12	na	0.07	0.00 - 0.13	na	na	0.00 - 0.00
µg/m3	AR	0.08	0.05	0.00 - 0.14	na	0.06	0.01 - 0.16	na	0.02	0.00 - 0.08
	FNR	0.03	0.05	0.04 - 0.06	na	0.02	0.00 - 0.03	na	NA	0.00 - 0.00
	FR	0.00	0.05	0.00 - 0.17	na	0.00	0.00 - 0.00	na	0.02	0.00 - 0.09
	FRC	0.02	0.09	0.06 - 0.12	na	0.00	0.00 - 0.00	na	0.03	0.00 - 0.06
	MC	0.08	0.00	0.00 - 0.00	na	na	na - na	na	na	na - na
PM10 Cr	ANR	0.01	0.02	0.00 - 0.04	na	0.00	0.00 - 0.01	na	na	0.00 - 0.00
µg/m3	AR	0.03	0.01	0.00 - 0.01	na	0.01	0.00 - 0.02	na	0.01	0.00 - 0.03
	FNR	0.02	0.01	0.00 - 0.02	na	0.01	0.01 - 0.02	na	NA	0.00 - 0.00
	FR	0.01	0.02	0.00 - 0.04	na	0.01	0.00 - 0.03	na	0.01	0.00 - 0.05
	FRC	0.00	0.01	0.00 - 0.01	na	0.01	0.00 - 0.03	na	0.03	0.00 - 0.04
	MC	0.02	0.02	0.01 - 0.02	na	na	na - na	na	na	na - na
PM10 Mn	ANR	0.02	0.00	0.00 - 0.01	na	0.00	0.00 - 0.00	na	na	0.00 - 0.00
µg/m3	AR	0.00	0.01	0.00 - 0.02	na	0.01	0.00 - 0.01	na	0.00	0.00 - 0.02
	FNR	0.02	0.00	0.00 - 0.01	na	0.01	0.00 - 0.02	na	NA	0.00 - 0.00
	FR	0.01	0.02	0.00 - 0.05	na	0.01	0.00 - 0.03	na	0.02	0.00 - 0.05
	FRC	0.04	0.01	0.00 - 0.03	na	0.01	0.00 - 0.02	na	0.02	0.01 - 0.03
	MC	0.01	0.00	0.00 - 0.00	na	na	na - na	na	na	na - na
PM10 Ni	ANR	0.01	0.02	0.01 - 0.03	na	0.00	0.00 - 0.00	na	na	0.00 - 0.00
µg/m3	AR	0.02	0.01	0.00 - 0.03	na	0.01	0.00 - 0.01	na	0.00	0.00 - 0.01
	FNR	0.01	0.01	0.01 - 0.01	na	0.01	0.01 - 0.01	na	NA	0.00 - 0.00
	FR	0.01	0.01	0.00 - 0.02	na	0.01	0.00 - 0.03	na	0.00	0.00 - 0.01
	FRC	0.01	0.02	0.00 - 0.04	na	0.01	0.00 - 0.01	na	0.01	0.00 - 0.03
	MC	0.02	0.01	0.01 - 0.02	na	na	na - na	na	na	na - na
PM10 Pb	ANR	0.02	0.02	0.00 - 0.05	na	0.00	0.00 - 0.01	na	na	0.00 - 0.00
µg/m3	AR	0.00	0.00	0.00 - 0.01	na	0.01	0.00 - 0.02	na	0.02	0.00 - 0.06
	FNR	0.00	0.00	0.00 - 0.00	na	0.00	0.00 - 0.00	na	NA	0.00 - 0.00
	FR	0.00	0.00	0.00 - 0.01	na	0.01	0.00 - 0.02	na	0.00	0.00 - 0.02
	FRC	0.00	0.01	0.00 - 0.01	na	0.00	0.00 - 0.00	na	0.03	0.00 - 0.06
	MC	0.03	0.01	0.00 - 0.01	na	na	na - na	na	na	na - na
PM10 S	ANR	2.26	1.72	1.63 - 1.80	na	1.62	1.51 - 1.73	na	na	0.00 - 0.00
µg/m3	AR	3.62	2.63	1.63 - 3.45	na	2.77	1.68 - 4.05	na	3.73	1.59 - 5.24
	FNR	1.69	1.65	0.72 - 2.57	na	1.74	0.76 - 2.73	na	NA	0.00 - 0.00
	FR	1.56	1.33	0.88 - 1.53	na	1.09	0.71 - 1.35	na	1.68	1.29 - 2.19
	FRC	4.73	3.17	2.19 - 4.15	na	3.07	2.20 - 3.94	na	4.15	3.20 - 5.13
	MC	2.75	2.30	2.02 - 2.58	na	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5D. Summary of PM2.5 Pollutant Commute-Average Concentration Data for Los Angeles

		Concentrations								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
PM 2.5 mass	ANR	63.5	67.7	49.3 - 86.0	73.1	56.4	41.1 - 71.7	49.2	NA	0.0 - 0.0
µg/m3	AR	48.0	41.0	28.5 - 53.1	64.0	32.9	22.6 - 45.1	38.6	52.9	10.3 - 102.8
	FNR	33.3	54.7	50.5 - 59.0	68.3	44.9	42.8 - 47.0	47.2	NA	0.0 - 0.0
	FR	32.1	45.4	36.1 - 56.0	53.7	32.1	22.7 - 38.9	42.1	44.7	35.3 - 76.0
	FRC	58.1	46.9	39.3 - 54.6	41.2	43.3	39.1 - 47.5	78.9	69.7	61.8 - 78.1
	MC	21.3	83.0	59.3 - 106.7	88.9	na	na - na	na	na	na - na
PM2.5 Cd	ANR	0.01	0.06	0.01 - 0.11	0.00	0.01	0.00 - 0.02	0.06	NA	0.00 - 0.00
µg/m3	AR	0.03	0.02	0.00 - 0.08	0.07	0.09	0.00 - 0.15	0.03	0.03	0.00 - 0.08
	FNR	0.09	0.01	0.00 - 0.02	0.04	0.05	0.00 - 0.10	0.08	NA	0.00 - 0.00
	FR	0.01	0.00	0.00 - 0.00	0.06	0.04	0.01 - 0.07	0.01	0.04	0.00 - 0.10
	FRC	0.09	0.01	0.00 - 0.02	0.07	0.07	0.07 - 0.08	0.00	0.03	0.00 - 0.09
	MC	0.05	0.00	0.00 - 0.00	0.00	na	na - na	na	na	na - na
PM2.5 Cr	ANR	0.02	0.01	0.00 - 0.03	0.01	0.03	0.03 - 0.03	0.04	NA	0.00 - 0.00
µg/m3	AR	0.00	0.02	0.01 - 0.04	0.00	0.00	0.00 - 0.00	0.02	0.01	0.00 - 0.04
	FNR	0.03	0.00	0.00 - 0.00	0.01	0.00	0.00 - 0.00	0.01	NA	0.00 - 0.00
	FR	0.02	0.01	0.00 - 0.03	0.01	0.00	0.00 - 0.02	0.00	0.02	0.00 - 0.05
	FRC	0.03	0.00	0.00 - 0.00	0.00	0.02	0.01 - 0.02	0.03	0.03	0.00 - 0.05
	MC	0.01	0.01	0.00 - 0.02	0.03	na	na - na	na	na	na - na
PM2.5 Mn	ANR	0.00	0.01	0.00 - 0.01	0.02	0.03	0.02 - 0.04	0.00	NA	0.00 - 0.00
µg/m3	AR	0.00	0.01	0.00 - 0.02	0.00	0.00	0.00 - 0.01	0.01	0.00	0.00 - 0.03
	FNR	0.03	0.00	0.00 - 0.00	0.00	0.00	0.00 - 0.01	0.00	NA	0.00 - 0.00
	FR	0.00	0.01	0.00 - 0.02	0.01	0.00	0.00 - 0.01	0.01	0.01	0.00 - 0.03
	FRC	0.00	0.01	0.00 - 0.03	0.00	0.00	0.00 - 0.00	0.00	0.00	0.00 - 0.01
	MC	0.01	0.00	0.00 - 0.01	0.00	na	na - na	na	na	0.00 - 0.00
PM2.5 Ni	ANR	0.00	0.01	0.00 - 0.02	0.01	0.02	0.01 - 0.03	0.00	NA	0.00 - 0.00
µg/m3	AR	0.01	0.00	0.00 - 0.02	0.00	0.00	0.00 - 0.01	0.01	0.01	0.00 - 0.03
	FNR	0.00	0.01	0.01 - 0.02	0.01	0.00	0.00 - 0.01	0.02	NA	0.00 - 0.00
	FR	0.01	0.00	0.00 - 0.01	0.00	0.00	0.00 - 0.01	0.01	0.00	0.00 - 0.01
	FRC	0.01	0.00	0.00 - 0.01	0.01	0.01	0.00 - 0.02	0.01	0.01	0.00 - 0.02
	MC	0.00	0.02	0.02 - 0.02	0.00	na	na - na	na	na	na - na
PM2.5 Pb	ANR	0.02	0.03	0.00 - 0.06	0.04	0.02	0.02 - 0.03	0.01	NA	0.00 - 0.00
µg/m3	AR	0.00	0.01	0.00 - 0.03	0.00	0.01	0.00 - 0.02	0.01	0.01	0.00 - 0.02
	FNR	0.02	0.01	0.00 - 0.01	0.04	0.01	0.00 - 0.02	0.03	NA	0.00 - 0.00
	FR	0.01	0.02	0.00 - 0.03	0.01	0.01	0.00 - 0.03	0.00	0.02	0.00 - 0.04
	FRC	0.01	0.02	0.01 - 0.02	0.01	0.01	0.00 - 0.03	0.02	0.02	0.00 - 0.06
	MC	0.00	0.00	0.00 - 0.00	0.00	na	na - na	na	na	na - na
PM2.5 S	ANR	1.97	1.73	1.69 - 1.77	1.76	1.62	1.47 - 1.77	1.50	NA	0.00 - 0.00
µg/m3	AR	3.09	2.44	1.68 - 2.98	3.02	2.27	1.49 - 2.60	2.37	3.20	1.38 - 4.30
	FNR	1.71	1.60	0.74 - 2.47	1.79	1.34	0.80 - 1.89	1.82	NA	0.00 - 0.00
	FR	1.34	1.33	0.97 - 1.54	1.41	1.18	0.73 - 1.49	1.24	1.49	0.99 - 1.85
	FRC	4.08	3.08	2.22 - 3.94	2.33	2.82	2.03 - 3.62	3.23	3.62	2.55 - 4.65
	MC	2.06	2.10	2.03 - 2.17	2.29	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5E. Summary of Commute-Average Associated Data for Los Angeles

		Other Measures								
Measure	Type	AMB Mean	IN 1 Mean	IN 1 Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Vehicle Speed (mph)	ANR	na	29.1	11.0 - 47.1	na	na	na - na	na	na	na - na
	AR	na	21.5	18.1 - 25.1	na	na	na - na	na	na	na - na
	FNR	na	47.6	37.0 - 58.2	na	na	na - na	na	na	na - na
	FR	na	42.1	37.4 - 46.7	na	na	na - na	na	na	na - na
	FRC	na	48.5	47.9 - 49.2	na	na	na - na	na	na	na - na
	MC	na	20.4	19.3 - 21.6	na	na	na - na	na	na	na - na
Spacing Range (feet)	ANR	na	55.5	54.2 - 56.7	na	na	na - na	na	na	na - na
	AR	na	55.2	49.2 - 67.3	na	na	na - na	na	na	na - na
	FNR	na	45.7	18.9 - 72.6	na	na	na - na	na	na	na - na
	FR	na	50.4	5.2 - 66.4	na	na	na - na	na	na	na - na
	FRC	na	88.1	87.1 - 89.0	na	na	na - na	na	na	na - na
	MC	na	67.8	64.4 - 71.2	na	na	na - na	na	na	na - na
Level of Congestion (unitless)	ANR	na	1.5	1.0 - 2.1	na	na	na - na	na	na	na - na
	AR	na	2.7	2.4 - 3.0	na	na	na - na	na	na	na - na
	FNR	na	3.6	3.0 - 4.3	na	na	na - na	na	na	na - na
	FR	na	3.3	2.9 - 3.7	na	na	na - na	na	na	na - na
	FRC	na	2.8	2.8 - 2.8	na	na	na - na	na	na	na - na
	MC	na	3.2	2.9 - 3.5	na	na	na - na	na	na	na - na
Miles Traveled	ANR	na	58.1	22.0 - 94.2	na	na	na - na	na	na	na - na
	AR	na	43.0	36.1 - 50.2	na	na	na - na	na	na	na - na
	FNR	na	95.2	74.1 - 116.4	na	na	na - na	na	na	na - na
	FR	na	84.2	74.8 - 93.4	na	na	na - na	na	na	na - na
	FRC	na	97.1	95.9 - 98.3	na	na	na - na	na	na	na - na
	MC	na	40.9	38.6 - 43.1	na	na	na - na	na	na	na - na
Heavy Duty Diesel Bus Influence (% of commute	ANR	na	6%	5% - 8%	na	na	na - na	na	na	na - na
	AR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FNR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FRC	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	MC	na	15%	0% - 30%	na	na	na - na	na	na	na - na
Heavy Duty Diesel Truck Influence (% of commute	ANR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	AR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FNR	na	45%	0% - 91%	na	na	na - na	na	na	na - na
	FR	na	77%	71% - 87%	na	na	na - na	na	na	na - na
	FRC	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	MC	na	7%	0% - 14%	na	na	na - na	na	na	na - na
Diesel Influence (other types) (% of commute	ANR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	AR	na	1%	0% - 2%	na	na	na - na	na	na	na - na
	FNR	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	FR	na	5%	0% - 20%	na	na	na - na	na	na	na - na
	FRC	na	0%	0% - 0%	na	na	na - na	na	na	na - na
	MC	na	5%	0% - 10%	na	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 3-5F. Summary of Commute-Average Meteorological Data for Los Angeles (Ambient Site Only)

Measure	Type	AMB Mean	IN 1 Mean	AMB Range	OUT 1 Mean	IN 2 Mean	IN 2 Range	OUT 2 Mean	ROAD Mean	ROAD Range
Windspeed (mph)	ANR	5.5	na	2 - 9	na	na	na - na	na	na	na - na
	AR	5.6	na	3 - 9	na	na	na - na	na	na	na - na
	FNR	6.5	na	4 - 9	na	na	na - na	na	na	na - na
	FR	4.8	na	3 - 8	na	na	na - na	na	na	na - na
	FRC	5.3	na	3 - 8	na	na	na - na	na	na	na - na
	MC	6.5	na	4 - 10	na	na	na - na	na	na	na - na
Temp (deg. F)	ANR	86.8	na	87.0 - 87.0	na	na	na - na	na	na	na - na
	AR	71.9	na	72.0 - 72.0	na	na	na - na	na	na	na - na
	FNR	82.8	na	82.0 - 84.0	na	na	na - na	na	na	na - na
	FR	75.4	na	75.0 - 76.0	na	na	na - na	na	na	na - na
	FRC	73.8	na	74.0 - 74.0	na	na	na - na	na	na	na - na
	MC	73.3	na	73.0 - 74.0	na	na	na - na	na	na	na - na
Relative Humidity, %	ANR	36.8	na	31.0 - 42.5	na	na	na - na	na	na	na - na
	AR	54.6	na	53.0 - 56.5	na	na	na - na	na	na	na - na
	FNR	45.3	na	36.0 - 54.5	na	na	na - na	na	na	na - na
	FR	50.9	na	46.0 - 55.0	na	na	na - na	na	na	na - na
	FRC	54.0	na	53.5 - 54.5	na	na	na - na	na	na	na - na
	MC	51.0	na	47.5 - 54.5	na	na	na - na	na	na	na - na
Predominant Wind Direction (degrees)	ANR	225	na	na - na	na	na	na - na	na	na	na - na
	AR	none	na	na - na	na	na	na - na	na	na	na - na
	FNR	314	na	na - na	na	na	na - na	na	na	na - na
	FR	none	na	na - na	na	na	na - na	na	na	na - na
	FRC	252	na	na - na	na	na	na - na	na	na	na - na
	MC	none	na	na - na	na	na	na - na	na	na	na - na

Notes: a Expected n values by Los Angeles commute scenario Type are: ANR(2), FNR(2), AR(4), FR(4), FRC(2), and MC(2); exceptions to the n values in parentheses.

b Means and ranges computed from uncensored data

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

3.3.2 Pollutant Concentrations

A number of pollutants in several categories were quantified in this study. A suite of VOC's associated with vehicular emissions was identified by GC/MS analysis, as well as a suite of elements from integrated particle samples analyzed by X-Ray Fluorescence. Formaldehyde was quantified as the representative aldehyde. Additional measures included gravimetric mass concentrations for integrated $PM_{2.5}$ and PM_{10} samples, and integrated 2 hour averages from continuous CO, black carbon, and particle count by size.

In order to provide a summary description of the pollutant levels, not all of the pollutants will be discussed in detail on an individual basis. To simplify and focus the discussions of pollutants summaries, this report addresses primarily "target" pollutants selected to represent pollutant classes, specifically, MTBE for the VOC's, $PM_{2.5}$ and PM_{10} integrated mass, $PM_{2.5}$ and PM_{10} elemental sulfur, formaldehyde, CO, black carbon, and particle count by size (total <2.5 μm). In general, several observations apply to almost all pollutants:

- most pollutant levels were elevated inside and outside the vehicles, relative to either the roadside or ambient concentrations (see section 4.4.4),
- most pollutant levels were extremely low at the rural site, relative to any of the vehicular or roadway locations (see section 4.3.1),
- most pollutant levels were at least somewhat higher in Los Angeles than in Sacramento, undoubtedly due in part to the larger base of vehicular emissions (see Tables 3-4A-F and-5A-F),
- while insignificant differences were observed for gas phase pollutants inside and outside of the same vehicle, particle concentrations were typically significantly higher outside - attributed to losses in the vehicle ventilation systems (see section 4.4.3), overlaid on inherent mass losses (estimated as ~20%) for the outside samples drawn through the inlet line,
- the inside vehicle pollutant concentrations for some individual commutes were substantially influenced by the tailpipe exhaust emissions from single polluting lead vehicles (see section 4.4.1), and
- the difficulty in following a selected "target" vehicle was least likely to occur for an extended period during freeway rush commutes, suggesting that these commutes produced scenarios and concentration levels that were the most representative (see section 2.2.3).

The ranges of in-vehicle concentrations (not background-corrected) for target pollutants are summarized as follows:

VOC's (tables 3-4A & 3-5A)

The in-vehicle concentrations of isobutylene, 1,3-butadiene, DCM, MTBE, benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene were all significantly higher in Los Angeles than in Sacramento. The generally higher ambient concentrations of VOC's in Los Angeles must be considered to place the microenvironmental contributions into perspective (see section 3.3.3). Both TCFM and ETBE levels were too near (or below) the MQL for adequate quantification. Acetonitrile concentrations showed no consistent patterns and may have been confounded by unknown sources inside one or more of the vehicles. While the field and lab blank data ruled Theout any possible laboratory contamination, cross-contamination between the exhausts of the acetonile-prepared DNPH cartridges and the VOC canister inlets may have periodically occurred.

In general, the in-vehicle levels for VOC's were very similar between Vehicle 1 and Vehicle 2.

The target fuel additive MTBE ranged from ~6 to 36 μg/m³ in Sacramento (excluding the rural commute), while the comparable in-vehicle range in Los Angeles was from ~24 to 90 μg/m³. Since most of the other quantified VOC's have sources outside the vehicular microenvironment, MTBE is perhaps the most robust VOC "tracer" for exhaust emissions and fuel losses.
Other in-vehicle VOC concentration ranges were:

- Isobutylene range from 3 to 14 μg/m3 in SAC, and 12 to 25 μg/m3 in LA,
- 1,3-Butadyiene range from 1 to 4 μg/m3 in SAC, and 2 to 6 μg/m3 in LA,
- Acetonitrile range from 18 to 345 μg/m3 in SAC, and 6 to 375 □μg/m3 in LA,
- TCFM was <MQL in SAC, and in LA,
- DCM range from 1 to 4 μμg/m3 in SAC, and 1 to 5 μg/m3 in LA,
- ETBE range from 0 to <1 μg/m3 in SAC, and 0 to <1 μg/m3 in LA,
- Benzene range from 3 to 15 μg/m3 in SAC, and 10 to 22 μg/m3 in LA,
- Toluene range from 7 to 46 μg/m3 in SAC, and 22 to 54 μg/m3 in LA,
- Ethylbenzene range from 2 to 10 μg/m3 in SAC, and 5 to 12 μg/m3 in LA,
- m,p-Xylene range from 5 to 38 μg/m3 in SAC, and 18 to 45 μg/m3 in LA,
- o-xylene range from 2 to 13 μg/m3 in SAC, and 6 to 16 μg/m3 in LA.

Formaldehyde (tables 3-4A & 3-5A)

Formaldehyde was also dramatically higher inside Los Angeles vehicles than those in Sacramento. Sacramento levels ranged from ~5 to 14 μg/m³ , while the range in LA was ~14 to 22 μg/m³ . Similar to the VOC's, however, the ambient background levels provided a large portion of this difference.

Carbon Monoxide (CO) (tables 3-4B & 3-5B)

The MQL of the study CO monitor (2 ppm) produced no measurable results at the ambient sites, but showed much higher levels inside the vehicles. The CO concentrations ranged from less than 1 to 2.6 ppm in Sacramento, and from 3 to 6 ppm in Los Angeles.

Black Carbon (tables 3-4B & 3-5B)

Black (soot) carbon is produced primarily from incomplete fuel combustion (most notably from diesel engines). The black carbon particles are typically <0.5 μm in size, and may contribute significantly to particle count, but minimally to particle mass (e.g. $PM_{2.5}$) unless a strong source is nearby. The continuous measures for black carbon and particle count by size were made inside and outside Vehicle 1 only, such that no comparison could be made with other locations, especially the ambient background. Black carbon concentrations ranged from zero to ~10 μg/m³ in Sacramento, and from ~3 to 23 μg/m³ in LA. This measure appeared to be strongly influenced by the presence of the diesel "target" vehicles.

Particle Count (by size) (tables 3-4B & 3-5B)

The total particle count (between 0.15 and 2.5 μm) is strongly influenced by vehicular emissions, but is also dependent on other sources, including the level of photochemistry. Thus, the background (not measured) particle count levels in Los Angeles would be expected to be significantly higher than Sacramento, based on only the generally higher level of photochemical activity. The total particle counts/cm^3 (multiply by 60 to obtain total particles counted/minute) ranged from ~20 to 1,200 in Sacramento (excluding rural), while those in LA ranged from ~ 2,200 to 4,600. Although estimates of integrated particle mass can be made (see Pilot Study report in Appendix A) by computing particle volumes and applying composite densities, it was decided for this report that the number and validity of the assumptions required for these computations did not merit going beyond count for the Main Study.

$PM_{2.5}$ and PM_{10} Mass (tables 3-4C, 3-4D & 3-5C, 3-5D)

Particle concentrations inside vehicles were substantially lower in Sacramento compared to Los Angeles. The $PM_{2.5}$ mass in-vehicle concentrations ranged from ~4 to 22 μg/m^3 in Sacramento, and ~29 to 107 μg/m^3 in LA. Similarly, the PM_{10} mass concentrations ranged from ~14 to 39 μg/m^3 in Sacramento, compared to ~46 to 105 μg/m^3 in LA. Comparisons between inside and outside concentration levels for $PM_{2.5}$ should consider the approximate 20% line loss during sampling for the OUT samples. This is discussed subsequently in sections 4.4.3 and 4.4.4. No outside samples were collected for PM_{10} . The substantial contributions of localized, nearby source (e.g. turbulent resuspension, construction activities, etc.) to PM_{10} concentrations severely reduces the validity of subtracting the Ambient site measure as a representative "background". Ambient $PM_{2.5}$ concentrations are expected to be much more uniformly distributed.

$PM_{2.5}$ and PM_{10} Elements (tables 3-4C, 3-4D & 3-5C, 3-5D)

The limited total mass collections at 4 lpm for 2 hours, greatly reduced the ability of XRF to provide concentration >MDL for many elements. Of the "target" elements, only elemental sulfur showed measurable concentrations for almost all commutes. These data provide an upper limit for particle elements, based on the MDL's provided in tables 3-3B and 3-3D. The ranges of $PM_{2.5}$ elemental sulfur were ~0.1 to 0.9 in Sacramento, and ~0.7 to 3.0 in Los Angeles. PM_{10} sulfur levels were nearly identical to $PM_{2.5}$, suggesting that almost all of the sulfur was <2.5 μm. Since most ambient elemental sulfur is reported to be sulfate, the elemental sulfur concentrations can be multiplied by 3 to approximate the SO_4 concentrations. For the non-target elements (see Appendix I), only Fe, K, Na, Si, Cu, and P were routinely elevated above the MQL for $PM_{2.5}$ for Sacramento or LA. Similarly, Na, Mg, Al, Si, P, K, Ca, Fe, Cu, and Zn were frequently elevated above the MQL for PM_{10} .

3.3.3 Ambient Background Influence

A review of the pollutant data for this study indicated that the ambient background concentrations in both Sacramento and Los Angeles were very important contributors to the observed concentrations measured inside and immediately outside the vehicles, and at the roadside locations. Evaluation of the influences of specific commuting factors (e.g. roadway type, time of day), suggests that the "background" be subtracted from the microenvironmental concentration - i.e. these factors were expected to influence the commuting microenvironment, not the

background. The research objectives for this study, however, did not require that the representativeness of the ambient site data of the true background for each pollutant be established. While it is recognized that the ambient data are not necessarily unbiased estimates of the true background during every commute, they represent the most reasonable data available. While gaseous pollutants and fine particles (e.g. $PM_{2.5}$) are generally assumed to be relatively uniform across a modest distance in a metropolitan area, PM_{10} could be expected to be much less uniform. Estimating the representativeness of the ambient data for PM_{10} , however, is beyond the scope of this effort.

The simplest way to assess the contribution of the commuting microenvironment was to subtract the ambient site data (if available) from the observed concentrations for each measure to estimate the vehicular contributions. An example of this data review is shown in Figure 3-1 plotting the trend data for all commutes for MTBE and benzene inside Vehicle 1 (IN 1) along with their ambient (AMB) concentrations. These plots tended to show that the in-vehicle number were typically higher than the ambient and correlated. Further analysis for selected pollutants (see Figure 3-2) showed that scatter plotting AMB (X) against the IN 1 values (Y) confirmed the increase in concentrations above background for most pollutants. It was noted (and discussed subsequently in Section 4.4.3) that the inside particle concentrations in all vehicles (IN1 or IN2, except in the school bus with the windows open) were substantially less than the associated outside concentrations (OUT1, OUT2), apparently resulting from particle losses while penetrating the vehicle ventilation system. Plotting AMB versus outside for Vehicle 1 (OUT 1) in Figure 3-3 represents the microenvironmental concentration immediately outside the vehicle, but is also biased from the estimated 19 to 21 % loss in the sampling line. Note also that the roadside $PM_{2.5}$ (ROAD 1) values plotted on this graph show higher concentrations than the ambient. A review of all the pollutant data with significant ambient concentration (CO background levels were below the MQL), showed that the ambient levels represented a significant and relatively consistent portion of the vehicular measurements. This suggested that it was important to estimate the incremental contribution of the commuting microenvironment to the existing background levels. It was also apparent that several other factors influence the in-vehicle concentrations, even after compensating for the ambient background. Figure 3-4 plots the daily MTBE and benzene levels, corrected for ambient (IN 1 - AMB) along with the ambient windspeed. Note that excluding the MTBE data point representing the special study school bus (SB) day, the vehicular contributions in Sacramento and Los Angeles are relative consistent, with Los Angeles being similarly consistent, but slightly higher. More importantly, as the wind speed decreased in Los Angeles, the vehicular contribution consistently increased (as might be expected).

An ambient site is located to represent the concentrations for a defined spatial area of the population. It is normally located to be generally unaffected by nearby single sources. If the ambient site were to serve as a measure of the "background" component, it should have a relatively consistent meteorology to stabilize transport processes. A review of the wind direction data for Sacramento and Los Angeles for each commute (see Figure 3-5) indicated that a predominant direction existed for the majority of the sampling periods in each city. In Los Angeles it was observed that the PM wind speeds were consistently higher than those in the AM, potentially affecting the rate of source plume dilutions.

Figure 3-1. ARB Main Study Raw MTBE and Benzene Data Comparing Trends for IN 1 and AMB

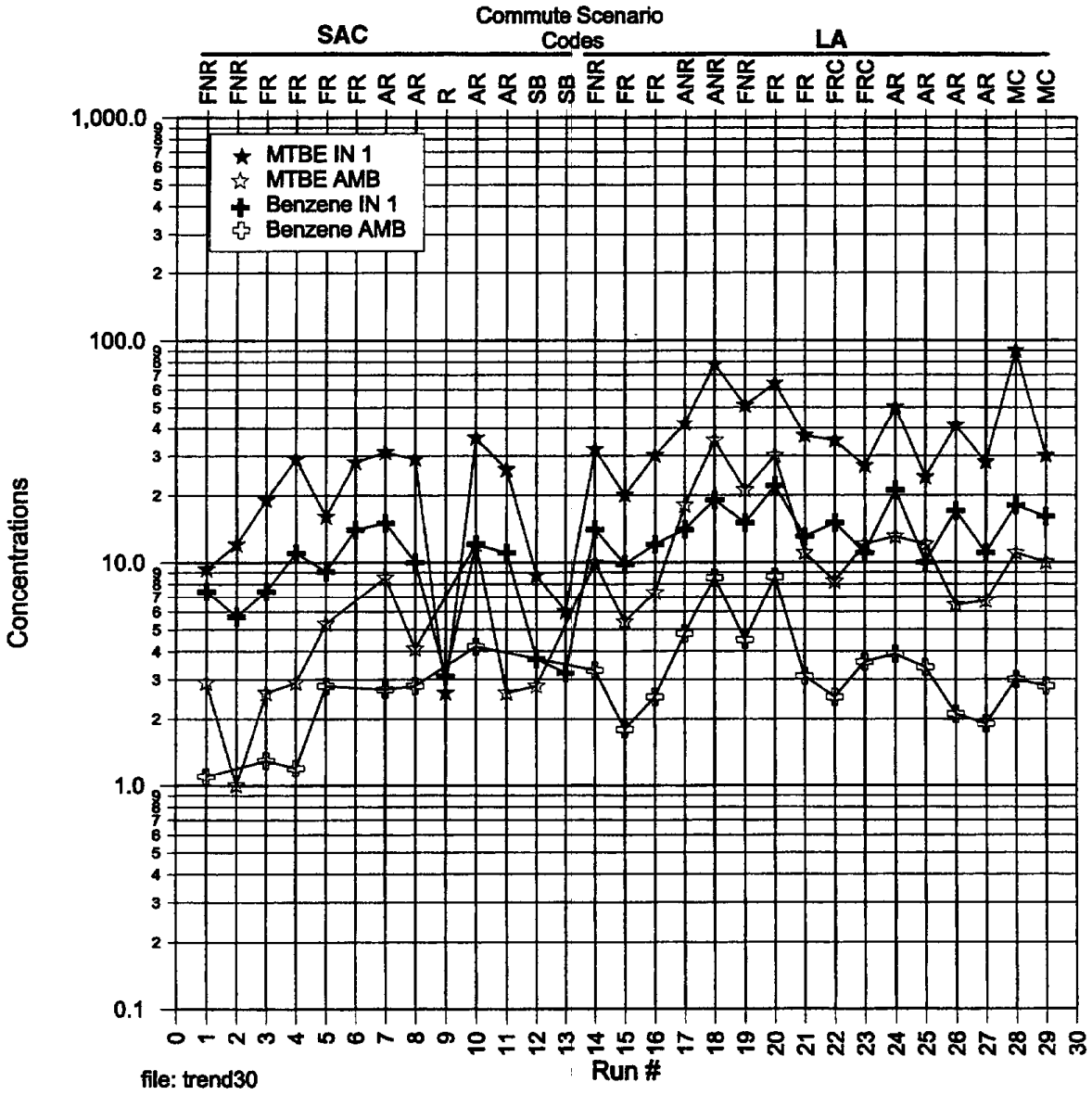


Figure 3-2. ARB Main Study Vehicle Study Ambient Concentration versus Inside Vehicle 1 Concentration for MTBE and Benzene for Sacramento and Los Angeles

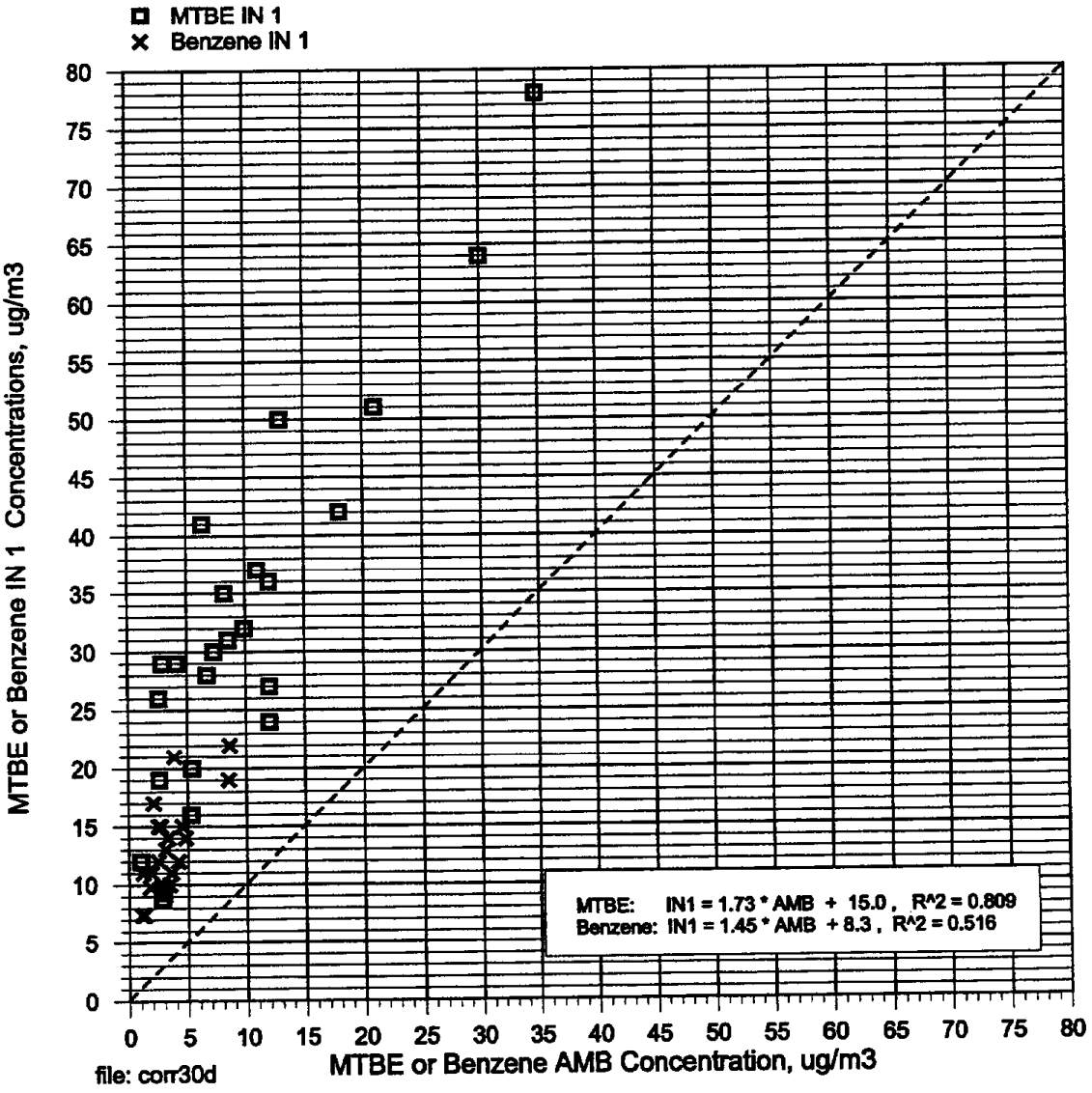


Figure 3-3. ARB Main Study Vehicle Study Ambient PM2.5 Mass Concentration versus Outside Vehicle 1 and Roadside 1 Mass Concentrations in Los Angeles

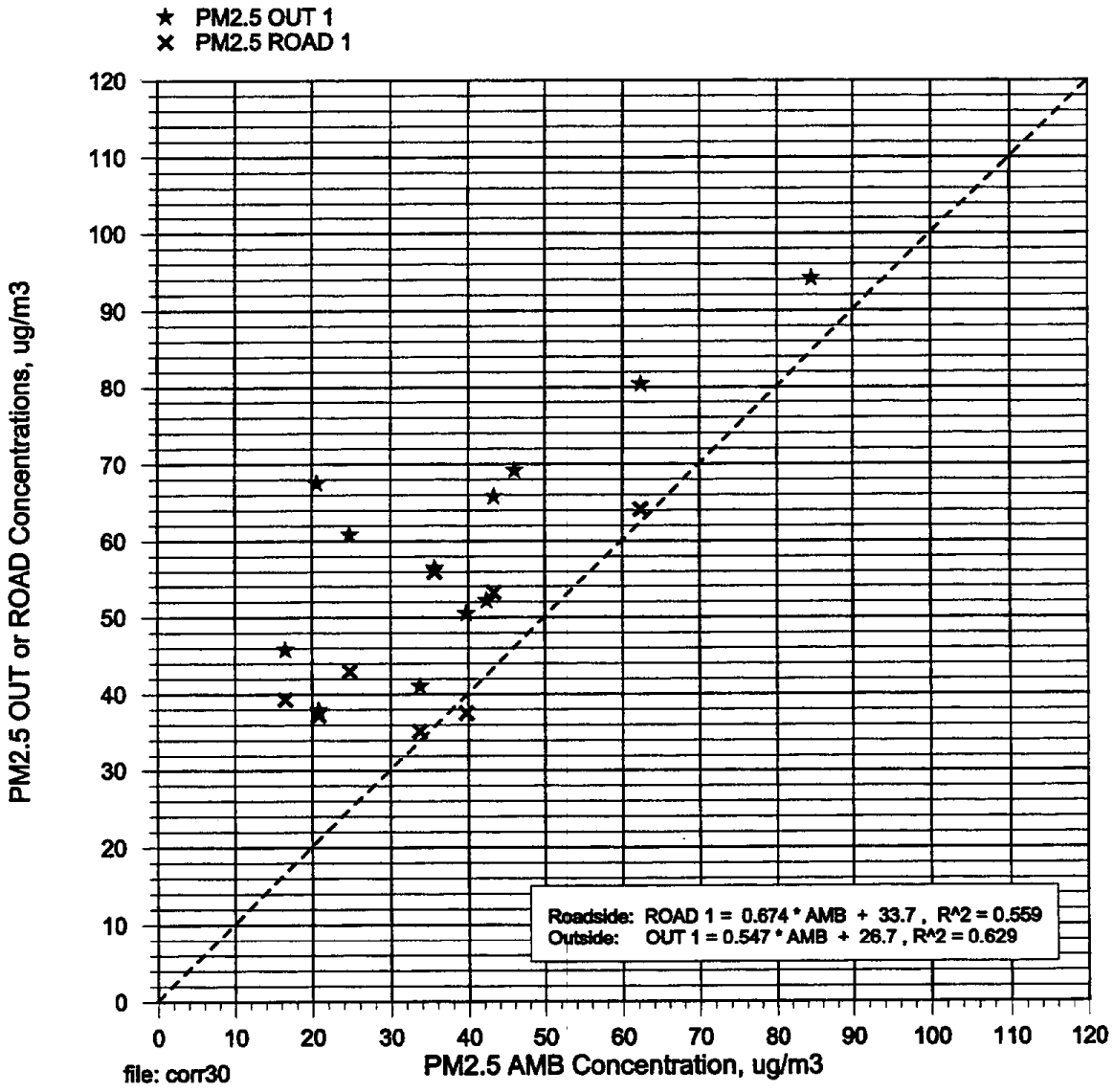


Figure 3-4. ARB Main Study Ambient-Corrected MTBE and Benzene Data

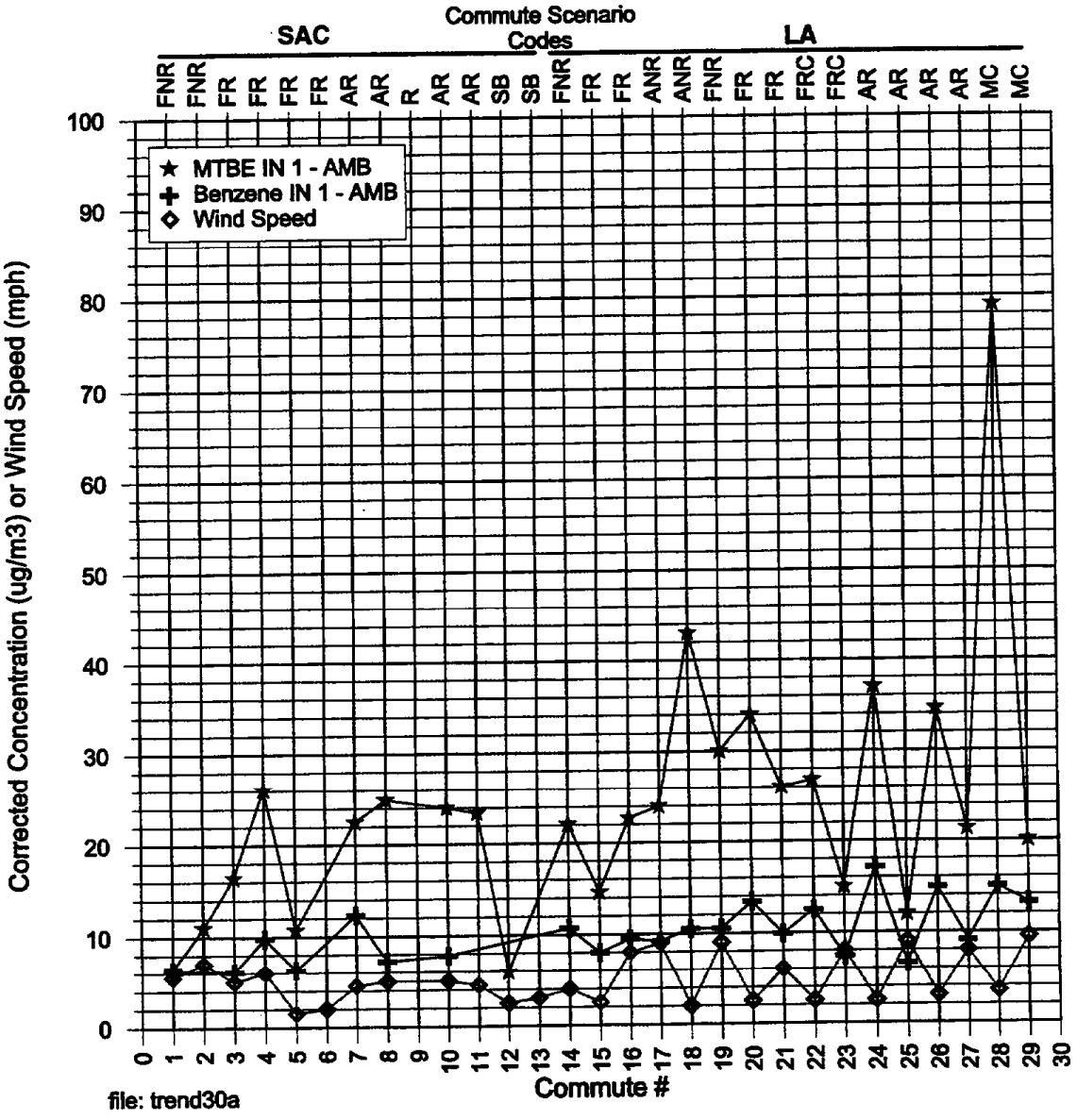
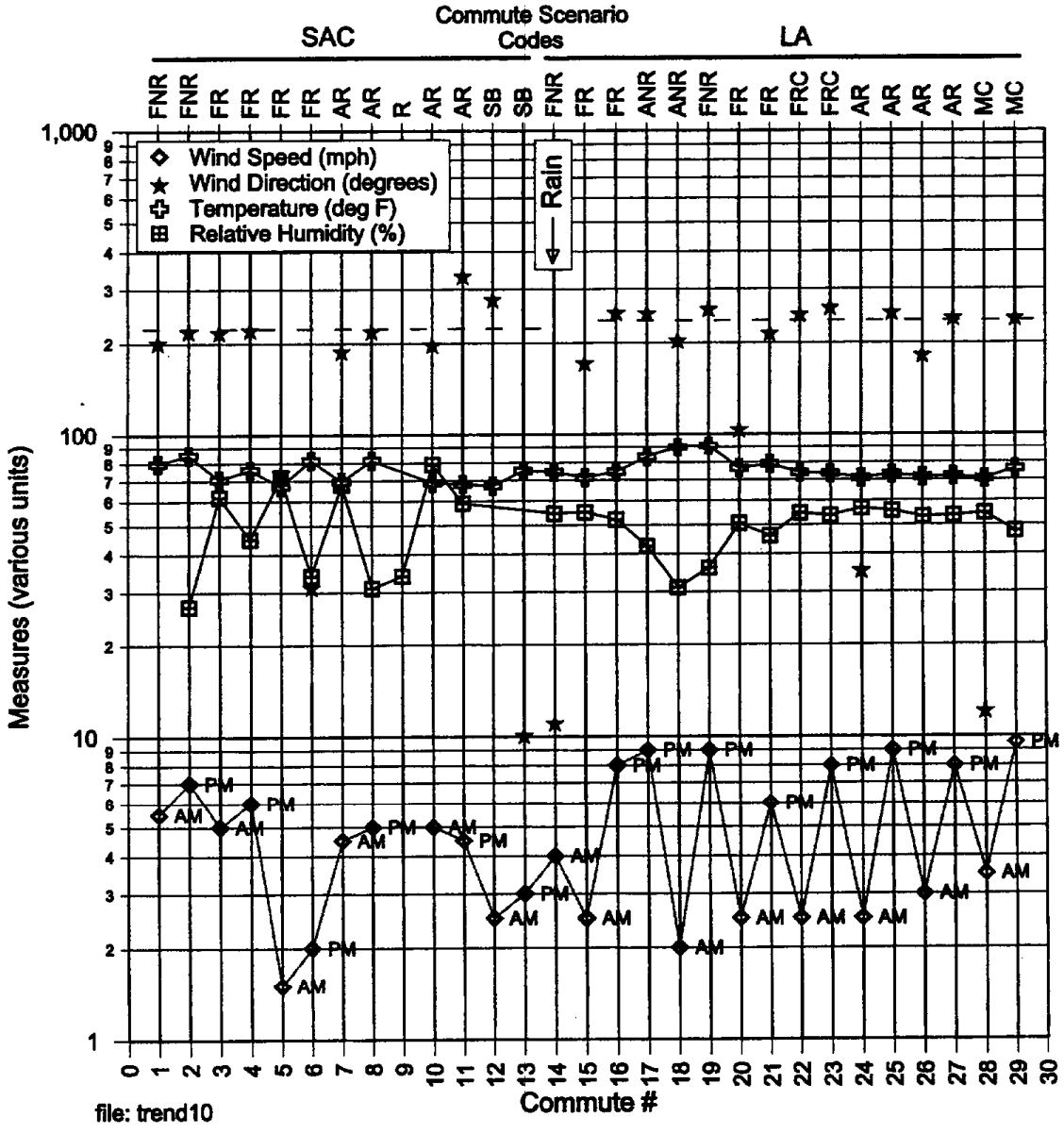


Figure 3-5. ARB Main Study Raw Meteorology
Wind Speed, Wind Direction, Temperature,
and Relative Humidity



The subsequent data analyses in Section 4 typically focus on the ambient-corrected concentrations that could be associated with the increment contributed by the vehicular microenvironment. The ambient concentrations are provided in each instance, however, in order to assess the contribution above background.

3.3.4 Vehicular Measures

Vehicular summaries for mean speed, vehicle spacing (mean trailing distance of Vehicle 1 to the vehicles immediately ahead), miles traveled, fraction of time Vehicle 1 was directly behind an identified diesel vehicle, and Level of Congestion [a subjective scale from 1 (very light traffic density) to 6 (heavy density approaching a standstill)] are given in Table 3-4E for Sacramento and Table 3-5E for Los Angeles.

A general comparison can be made between Sacramento and Los Angeles for the AR and FR categories as shown in Table 3-6. While the mean speed for AR is approximately the same in Sacramento and Los Angeles, the FR commutes in LA were significantly faster by 10 mph. This resulted in a larger number of miles traveled in LA (16 miles/ FR commute). The trailing distances in LA are significantly closer than in Sacramento, at approximately 20 feet closer for both AR and FR commutes. The Level of Congestion was essentially the same in Sacramento and LA for AR and FR, but the percentages of the time Vehicle 1 was trailing a diesel "target" vehicle were highly variable. Since a "smoking" diesel vehicle can significantly influence selected pollutant concentrations, even during short trailing events, the percentages of time under (subjective) diesel influence by type should be considered. It should be noted that some degree of uncertainty exists in these categorizations, even though the observers were experienced in characterizing vehicular traffic. This uncertainty arises from occasional difficulty in determining the fuel source for some vehicles, especially the light duty trucks counted in the "Other Diesel Influence" category.

Table 3-6. Comparison of Vehicular Measures for Selected Sacramento and Los Angeles Commutes

	Sacramento		Los Angeles	
Measure	**AR**	**FR**	**AR**	**FR**
Vehicle Speed, mph	23.8	32.5	21.5	42.1
Spacing, feet	74.4	68.9	55.2	50.4
Level of Congestion, unitless	2.5	3.9	2.7	3.3
Miles traveled	49.1	68.3	43.0	84.2
Diesel Bus Influence, %	4 %	22 %	0%	0%
Heavy Duty Diesel Truck Influence, %	0 %	47 %	0%	77%
Other Diesel Influence, %	0 %	7 %	1%	5%

3.3.5 Vehicle Air Exchange Rates

The air exchange rates were determined at constant vehicle speed (55 mph) for all vehicles, since it was expected that (a) the vent settings would significantly affect the AER, (b) low AER's

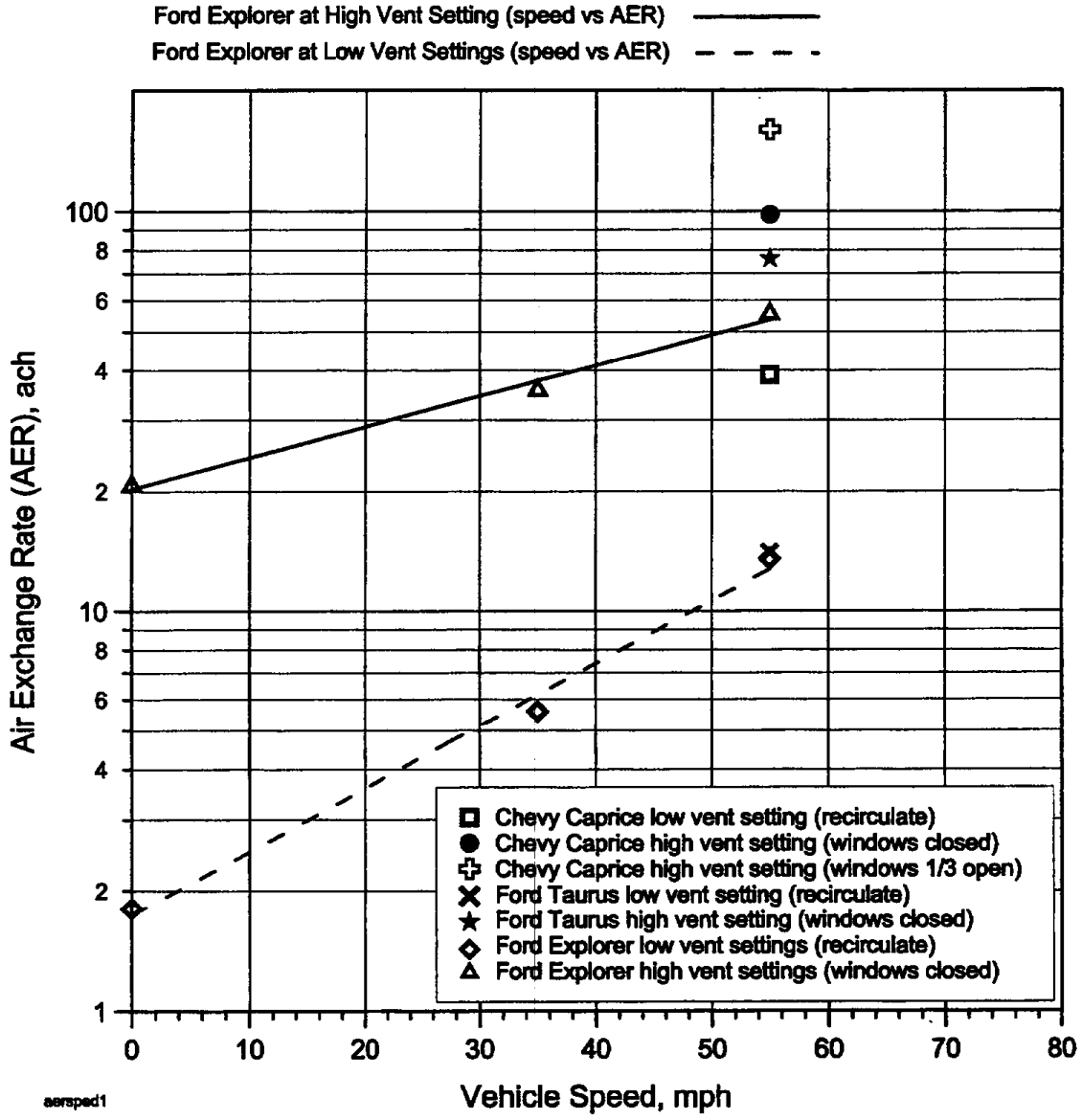
could have an "insulating" effect on relatively short-term (e.g. following a bus) pollutant concentration excursions. The tabulated air exchange data are given in Table 3-7 for each vehicle and ventilation setting. The Chevrolet Caprice and Ford Taurus AER's were determined at a constant speed of 55 mph. The Ford Explorer AER's were determined for a range of speeds (0, 35 and 55 mph) to illustrate the influence of vehicle speed on AER. The data are also plotted in Figure 3-6 , and indicate that vehicle speed versus AER is reasonably semi-logarithmic (based on very limited data). The low vent setting in the Explorer provided AER's that changed by almost an order of magnitude from 0 to 55 mph.

Table 3-7. Air Exchange Rate Data Summary for All Vehicles by Vent Setting and (Constant) Speed

	Low vent Setting			Medium vent Setting			High vent Setting		
Vehicle	0 mph	35 mph	55 mph	0 mph	35 mph	55 mph	0 mph	35 mph	55 mph
1991 Chevrolet Caprice	nd	nd	39	nd	nd	98	nd	nd	160
1997 Ford Taurus	nd	nd	14	nd	nd	76	nd	nd	nd
1997 Ford Explorer	1.8	5.6	13.5	20.7	35.7	55.5	nd	nd	nd

Note: These air exchange rate were determined for constant speed commutes to indicate the relative influence of vent settings.

Figure 3-6. ARB In-Vehicle Study
Constant Speed Air Exchange Rates
by Vehicle Type, Vent Setting, and Speed



4.0 DISCUSSION

The analysis of the data for this project is necessarily limited to the evaluating research study objectives. The obvious wealth of information contained in the data base, however, suggests that further data analyses by ARB beyond those presented here could be very fruitful. Only a few of the pollutant measures summarized (especially VOC's other than MTBE) are discussed in any detail, relative to the research objectives. While data are summarized for Vehicle 2 in each instance, the data for this second vehicle were reviewed in detail only to address the differences between vehicles in section 4.2.2.

4.1 Focus Pollutants

In order to discuss trends and data analyses in a simplified but focused manner for the evaluation of study design objectives, only a few selected pollutant measures representing general classes are addressed. Specifically, MTBE (and occasionally benzene) data were analyzed as a target VOC, $PM_{2.5}$ for particle mass, formaldehyde, CO, and occasionally, total particle count and $PM_{2.5}$ sulfur. Individual tables summarizing all commutes for $PM_{2.5}$ and PM_{10} mass, MTBE, formaldehyde, and carbon monoxide are provided in Appendix J. The special study commutes (Section 4.3) and selected data analyses (Section 4.4) address additional measures. The single source of the fuel additive, MTBE, provided the most consistent gas-phase pollutant relationships compared to all other pollutants. Almost every other pollutant is known to have multiple sources.

4.2 Evaluation of Study Design Objectives

The workplan for this project defined specific design objectives to guide the study design and the collection of data. These objectives (Table 1-2) were developed, based on the premise that commuter exposure (to concentrations over a time interval) were potentially influenced by a number of key factors. The factors considered are the influences of:

(A) the type of California vehicle being driven,
(B) the influence of driver-selected ventilation choices (window-up situations),
(C) the type of roadway,
(D) the differences between two California metro areas,
(E) the level of congestion on the roadways, and
(F) the general time of day period when the commute occurred.

The overall study design attempted to apply a balanced factorial scheme to allow relatively simple comparisons between the concentration means of various scenarios. The evaluation of these influences on in-vehicle concentration levels are addressed by appropriate organization of the means and data ranges. In most cases, the corrections have been made for the ambient "background" levels (if appropriate), prior to computing means. The ambient levels are provided in these tables to provide an indication of the magnitude of the background contributions. The special nature of the Rural (R), School Bus (SB), Freeway Rush Carpool (FRC), and Maximum Concentration (MC) commutes, suggested that these concentrations not be included in the computations assessing the study design objectives in Section 4.2. The special study commutes are addressed separately in section 4.3.

The driving protocols defined in Section 2.3 have a substantial influence on the data analyses. Some of the key points in these protocols are: (1) trailing single polluting "target" vehicles, even for relatively short periods, may have significantly influenced the 2 hour commute averages for selected pollutants, (2) combining "significantly" influenced commutes into a single scenario composite with a relatively small sample size, may have provided a somewhat misleading picture for certain pollutants, (3) the tandem nature of the commutes, with Vehicle 2 almost always trailing Vehicle 1, sometimes exposed Vehicle 2 to higher concentrations for some pollutants, and (4) the limited number of vehicle types and ventilation settings evaluated. The factors of small sample sizes for each scenario (freeway rush, arterial rush, etc.) and the potential for single vehicle influences in a given commute, combine to suggest that these data analyses are not to be considered as necessarily definitive, but generally indicative of the ranges of concentrations that could be encountered in similar commutes.

4.2.1 Ventilation Setting Influence (High vs Low)

Tables 4-1 (A thru D) summarize the concentration data for non-special commutes for all measures focusing on the influence of "low" and "high" ventilation setting on the in-vehicle concentration levels. Mean values for IN 1, IN 2, OUT 1, and OUT 2 were computed for Sacramento (alone), Los Angeles (alone), and both cities, stratified by the "Low" or "High" ventilation setting for the commute (see Table 1-1 for vent settings). The ventilation settings for Vehicle 1 were identical in both cities. These means are uncorrected for ambient background. In order to estimate the penetration of each pollutant into the vehicles, the differences between the inside and outside values were computed for each vehicle and given in the last two columns to give (IN 1 - OUT 1) and (IN 2 - OUT 2). Note that these differences are the same whether or not the ambient background is subtracted. Vehicle 1 is the 1991 Chevrolet Caprice (sedan) in both cities. Vehicle 2 is a 1997 Ford Taurus (sedan) in Sacramento, and a 1997 Ford Explorer (SUV) in Los Angeles. Thus, the (IN 1 - OUT 1) column would be expected to be the same between cities for all measurement. The (IN 2 - OUT 2) column, however, could be different between cities. Since formaldehyde was not measured outside the vehicles, the influence of vent setting did not apply. The presumption is that the sources of the pollutants being addressed are external to the vehicles. Interior sources would confound such an analysis.

A review of the tabular data indicated relatively small differences for IN - OUT (relative to IN1) for both vehicles, for all of the VOC's except acetonitrile. The sources of this compound are not clear, and may have existed inside one or both vehicles. The particle-associated measures ($PM_{2.5}$ mass, particle count, black carbon-Aethalometer, and $PM_{2.5}$ S) tend to show that there is a distinct reduction in particle species penetrating the vehicles. What is apparent is a general lack of influence of the vehicle ventilation settings on the pollutant concentrations. A plot of (IN 1 - OUT 1) in Figure 4-1 for CO, MTBE, benzene, and $PM_{2.5}$ shows no consistent relationships of "Low" and "High" indicators for any of the pollutants (Low setting commutes highlighted with bold dashed lines). The general loss of $PM_{2.5}$ from outside to inside for $PM_{2.5}$ is apparent, but no significant influence of vent setting is shown. The measured loss is biased somewhat by the requirement for the outside vehicle samples to be drawn through a sample line. The accuracy of applying an individual commute correction factor for gravimetric particle data, based on optical particle counter

data, is undefined. A range of approximate loss factors of $PM_{2.5}$ mass was computed[6] for the Main Study commutes to be 19 to 21 %. An approximate 20% correction to the OUT 1 data was made and plotted in a manner similar to Figure 4-2, but the same conclusion was reached, that no apparent influence of vent settings on inside $PM_{2.5}$ concentrations was found. A similar plot for Vehicle 2 in Figure 4-2 for $PM_{2.5}$ again provided no relationship between vent setting and inside concentration. No judgements could be made for formaldehyde, since outside samples were not collected. For the vehicles tested, the vent settings utilized, and the relatively high AER's for most commutes, no significant influences of vent settings were apparent on the in-vehicle concentrations (by modifying the outside concentration levels).

[6] Using selected LAS-X particle size distributions for the arterial and freeway commutes, and applying the California aerosol densities determined by Kreisberg et al., 1998.

Table 4-1A. Influence of Vehicle Ventilation Settings on Organic Commute-Average Concentrations

				Concentrations (not corrected for Ambient) in Measure Units					
Measure	City	Vent Setting	AMB Mean	IN 1 Mean	IN 2 Mean	OUT 1 Mean	OUT 2 Mean	IN 1 mean - OUT 1 mean	IN 2 mean - OUT 2 mean
Isobutylene	Sac	Hi	1.8	9.0	8.9	8.0	8.3	1.1	0.6
µg/m3		Low	2.5	11.5	11.1	11.5	8.8	0.0	2.3
	LA	Hi	4.4	17.0	15.9	17.2	15.9	-0.2	0.1
		Low	6.6	19.5	18.9	20.3	18.5	-0.8	0.4
1,3-Butadiene	Sac	Hi	0.3	2.2	1.8	1.8	2.0	0.4	-0.2
µg/m3		Low	0.3	3.1	2.6	3.2	2.0	-0.1	0.6
	LA	Hi	0.4	3.5	3.0	3.5	2.9	0.0	0.1
		Low	0.8	4.0	3.3	4.2	3.4	-0.2	-0.1
Acetonitrile	Sac	Hi	17.9	59.7	52.0	1.7	35.5	58.0	16.5
µg/m3		Low	66.4	223.6	334.9	2.1	166.6	221.4	168.3
	LA	Hi	11.8	43.8	50.4	3.0	37.2	40.8	13.2
		Low	35.4	312.6	399.5	5.1	227.4	307.5	172.1
DCM	Sac	Hi	2.2	1.5	1.1	1.3	2.0	0.2	-0.9
µg/m3		Low	3.1	1.4	1.9	1.4	2.0	0.0	-0.1
	LA	Hi	6.3	2.6	3.4	3.2	3.2	-0.6	0.1
		Low	4.2	3.6	2.9	2.9	3.0	0.7	-0.1
MTBE	Sac	Hi	3.7	21.4	19.3	20.0	18.5	1.4	0.8
µg/m3		Low	5.4	26.6	19.6	24.4	17.4	2.2	2.2
	LA	Hi	13.6	40.2	34.5	40.7	34.8	-0.5	0.1
		Low	16.7	44.0	36.7	46.6	37.7	-2.6	-0.9
ETBE	Sac	Hi	0.3	0.1	0.1	0.2	0.5	-0.1	-0.4
µg/m3		Low	0.4	0.2	0.2	0.2	0.2	0.0	0.0
	LA	Hi	0.1	0.0	0.0	0.0	0.0	0.0	0.1
		Low	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TCFM	Sac	Hi	2.9	2.5	2.3	2.3	3.6	0.3	-1.3
µg/m3		Low	3.0	8.3	3.3	2.8	2.8	5.5	0.5
	LA	Hi	1.6	1.6	1.7	1.7	1.7	-0.2	0.1
		Low	2.1	1.7	1.7	1.8	1.7	0.0	0.0
Benzene	Sac	Hi	1.6	9.4	11.2	8.4	10.5	1.1	0.7
µg/m3		Low	2.3	11.6	11.9	11.9	11.0	-0.3	0.9
	LA	Hi	3.7	13.9	13.4	13.9	13.1	0.0	0.4
		Low	4.8	16.5	14.4	16.9	14.7	-0.4	-0.3
Toluene	Sac	Hi	5.9	22.2	23.5	19.5	24.0	2.7	-0.5
µg/m3		Low	6.9	40.6	24.4	27.4	21.7	13.1	2.7
	LA	Hi	22.9	36.1	31.6	35.1	32.0	1.0	0.1
		Low	14.4	40.4	31.1	41.0	33.1	-0.5	-2.0
Ethylbenzene	Sac	Hi	1.8	4.6	4.5	4.0	4.5	0.6	0.0
µg/m3		Low	1.4	8.2	5.2	6.2	4.7	2.0	0.5
	LA	Hi	2.0	7.3	6.1	7.1	6.1	0.2	0.1
		Low	2.6	8.7	5.9	8.4	6.4	0.3	-0.5
M,P-Xylene	Sac	Hi	2.7	19.4	18.2	16.1	17.6	3.3	0.6
mg/m3		Low	4.5	33.0	19.1	23.3	17.1	9.6	2.0
	LA	Hi	5.8	27.6	23.0	26.7	22.6	1.0	0.3
		Low	8.6	33.0	22.5	33.3	24.6	-0.3	-2.2
O-Xylene	Sac	Hi	1.2	6.7	6.4	5.7	6.5	1.0	-0.1
µg/m3		Low	2.3	11.2	6.7	8.2	6.5	2.9	0.1
		Low	3.3	11.6	8.4	11.9	9.0	-0.2	-0.6
Formaldehyde	Sac	Hi	4.2	6.0	4.5	na	na	na	na
µg/m3		Low	3.9	8.5	10.7	na	na	na	na
	LA	Hi	12.6	5.3	3.7	na	na	na	na
		Low	11.8	5.2	7.5	na	na	na	na

Notes: a Expected n values for Sacramento are: Hi - (6), Lo - (4)
Expected n values for Los Angeles are: Hi - (8), Lo - (4)
with exceptions to the n values in parentheses next to the mean.
b Means and ranges computed from uncensored data
c Values are ug/m3, unless noted otherwise in Measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-1B. Influence of Vehicle Ventilation Settings on Continuous Commute-Average Concentrations

				Concentrations (not corrected for Ambient) in Measure Units					
Measure	City	Vent Setting	AMB Mean	IN 1 Means	IN 2 Mean	OUT 1 Mean	OUT 2 Mean	IN 1 mean - OUT 1 mean	IN 2 mean - OUT 2 mean
CO Avg (ppm)	Sac	Hi	0.0	2.0	3.5	2.5	4.1	-0.5	-0.6
		Low	0.0	2.1	2.7	2.3	4.0	-0.2	-1.4
	LA	Hi	0.5	4.3	4.5	4.4	4.7	0.0	-0.2
		Low	0.5	4.9	5.3	5.4	6.1	-0.5	-0.8
CO Peak (ppm)	Sac	Hi	0.0	12.3	18.5	17.3	21.7	-4.9	-3.2
		Low	0.8	9.3	10.3	15.5	13.3	-6.3	-3.0
	LA	Hi	1.5	35.0	14.4	39.5	17.5	-4.5	-3.1
		Low	1.3	12.5	8.0	29.3	12.8	-16.8	-4.8
Black Carbon µg/m3	Sac	Hi	na	5.7	na	4.7	na	1.0	na
		Low	na	3.6	na	5.9	na	-2.4	na
	LA	Hi	na	11.6	na	15.2	na	-3.6	na
		Low	na	20.6	na	19.0	na	1.6	na
LASX mean total particle counts/cm3	Sac	Hi	na	841	na	1,680	na	-839	na
		Low	na	505	na	1,349	na	-845	na
	LA	Hi	na	3,305	na	6,261	na	-2,956	na
		Low	na	2,865	na	6,652	na	-3,786	na

Notes: a Expected n values for Sacramento are: Hi - (6), Lo - (4)
Expected n values for Los Angeles are: Hi - (8), Lo - (4)
with exceptions to the n values in parentheses next to the mean.
b Means and ranges computed from uncensored data
c Values are ug/m3, unless noted otherwise in Measure column
Ambient data not available to correct black carbon or LAS-X data
LAS-X OUT data corrected for sampling line losses
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-1C. Influence of Vehicle Ventilation Settings on PM10 Commute-Average Concentration Data

				Concentrations (not corrected for Ambient) in Measure Units					
Measure	City	Vent Setting	AMB Mean	IN 1 Means	IN 2 Mean	OUT 1 Mean	OUT 2 Mean	IN 1 mean - OUT 1 mean	IN 2 mean - OUT 2 mean
PM 10	Sac	Hi	22.7	25.8	8.1	na	na	na	na
µg/m3		Low	23.8	22.9	14.6	na	na	na	na
	LA	Hi	61.3	57.6	48.4	na	na	na	na
		Low	90.7	53.4	51.4	na	na	na	na
PM10 Cd	Sac	Hi	0.11	0.10	0.10	na	na	na	na
µg/m3		Low	0.10	0.10	0.10	na	na	na	na
	LA	Hi	0.10	0.11	0.10	na	na	na	na
		Low	0.10	0.10	0.11	na	na	na	na
PM10 Cr	Sac	Hi	0.40	0.40	0.40	na	na	na	na
µg/m3		Low	0.40	0.40	0.40	na	na	na	na
	LA	Hi	0.40	0.40	0.40	na	na	na	na
		Low	0.40	0.40	0.40	na	na	na	na
PM10 Mn	Sac	Hi	0.04	0.04	0.04	na	na	na	na
µg/m3		Low	0.04	0.04	0.04	na	na	na	na
	LA	Hi	0.04	0.04	0.04	na	na	na	na
		Low	0.04	0.04	0.04	na	na	na	na
PM10 Ni	Sac	Hi	0.03	0.03	0.03	na	na	na	na
µg/m3		Low	0.03	0.03	0.03	na	na	na	na
	LA	Hi	0.03	0.03	0.03	na	na	na	na
		Low	0.03	0.03	0.03	na	na	na	na
PM10 Pb	Sac	Hi	0.03	0.03	0.03	na	na	na	na
µg/m3		Low	0.03	0.04	0.03	na	na	na	na
	LA	Hi	0.03	0.03	0.03	na	na	na	na
		Low	0.03	0.03	0.03	na	na	na	na
PM10 S	Sac	Hi	0.46	0.43	0.32	na	na	na	na
µg/m3		Low	0.47	0.38	0.28	na	na	na	na
	LA	Hi	2.64	2.08	1.97	na	na	na	na
		Low	2.98	2.13	2.15	na	na	na	na

Notes: a Expected n values for Sacramento are: Hi - (6), Lo - (4)
Expected n values for Los Angeles are: Hi - (8), Lo - (4)
with exceptions to the n values in parentheses next to the mean.
b Means and ranges computed from uncensored data
c Values are ug/m3, unless noted otherwise in Measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-1D. Influence of Vehicle Ventilation Settings on PM2.5 Commute-Average Concentration Data

				Concentrations (not corrected for Ambient) in Measure Units					
Measure	City	Vent Setting	AMB Mean	IN 1 Means	IN 2 Mean	OUT 1 Mean	OUT 2 Mean	IN 1 mean - OUT 1 mean	IN 2 mean - OUT 2 mean
PM 2.5 µg/m3	Sac	Hi	5.9	13.3	7.6	18.9	11.2	-5.5	-3.6
		Low	12.4	11.3	11.0	21.1	16.9	-9.8	-5.9
	LA	Hi	36.2	49.8	40.6	58.5	39.9	-8.8	0.7
		Low	56.2	47.2	34.4	71.4	49.0	-24.2	-14.7
PM2.5 Cd µg/m3	Sac	Hi	0.10	0.10	0.10	0.10	0.10	0.00	0.00
		Low	0.10	0.10	0.12	0.10	0.10	0.00	0.02
	LA	Hi	0.11	0.10	0.10	0.10	0.10	0.00	0.00
		Low	0.10	0.10	0.10	0.10	0.10	0.00	0.00
PM2.5 Cr µg/m3	Sac	Hi	0.40	0.40	0.40	0.40	0.40	0.00	0.00
		Low	0.40	0.40	0.40	0.40	0.40	0.00	0.00
	LA	Hi	0.40	0.40	0.40	0.40	0.40	0.00	0.00
		Low	0.40	0.40	0.40	0.40	0.40	0.00	0.00
PM2.5 Mn µg/m3	Sac	Hi	0.04	0.04	0.04	0.04	0.04	0.00	0.00
		Low	0.04	0.04	0.04	0.04	0.04	0.00	0.00
	LA	Hi	0.04	0.04	0.04	0.04	0.04	0.00	0.00
		Low	0.04	0.04	0.04	0.04	0.04	0.00	0.00
PM2.5 Ni µg/m3	Sac	Hi	0.03	0.03	0.03	0.03	0.03	0.00	0.00
		Low	0.03	0.03	0.03	0.03	0.03	0.00	0.00
	LA	Hi	0.03	0.03	0.03	0.03	0.03	0.00	0.00
		Low	0.03	0.03	0.03	0.03	0.03	0.00	0.00
PM2.5 Pb µg/m3	Sac	Hi	0.03	0.03	0.03	0.03	0.03	0.00	0.00
		Low	0.03	0.03	0.03	0.05	0.03	-0.02	0.00
	LA	Hi	0.03	0.03	0.03	0.04	0.03	0.00	0.00
		Low	0.03	0.03	0.03	0.03	0.03	0.00	0.00
PM2.5 S µg/m3	Sac	Hi	0.46	0.49	0.33	0.54	0.45	-0.05	-0.12
		Low	0.39	0.35	0.27	0.38	0.33	-0.02	-0.06
	LA	Hi	1.87	1.72	1.62	1.84	1.67	-0.11	-0.05
		Low	2.54	1.99	1.70	2.53	1.94	-0.54	-0.24

Notes: a Expected n values for Sacramento are: Hi - (6), Lo - (4)
Expected n values for Los Angeles are: Hi - (8), Lo - (4)
with exceptions to the n values in parentheses next to the mean.
b Means and ranges computed from uncensored data
c Values are ug/m3, unless noted otherwise in Measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Figure 4-1. Differences Between Inside and Outside Concentrations by Vehicle Ventilation Setting for Vehicle 1

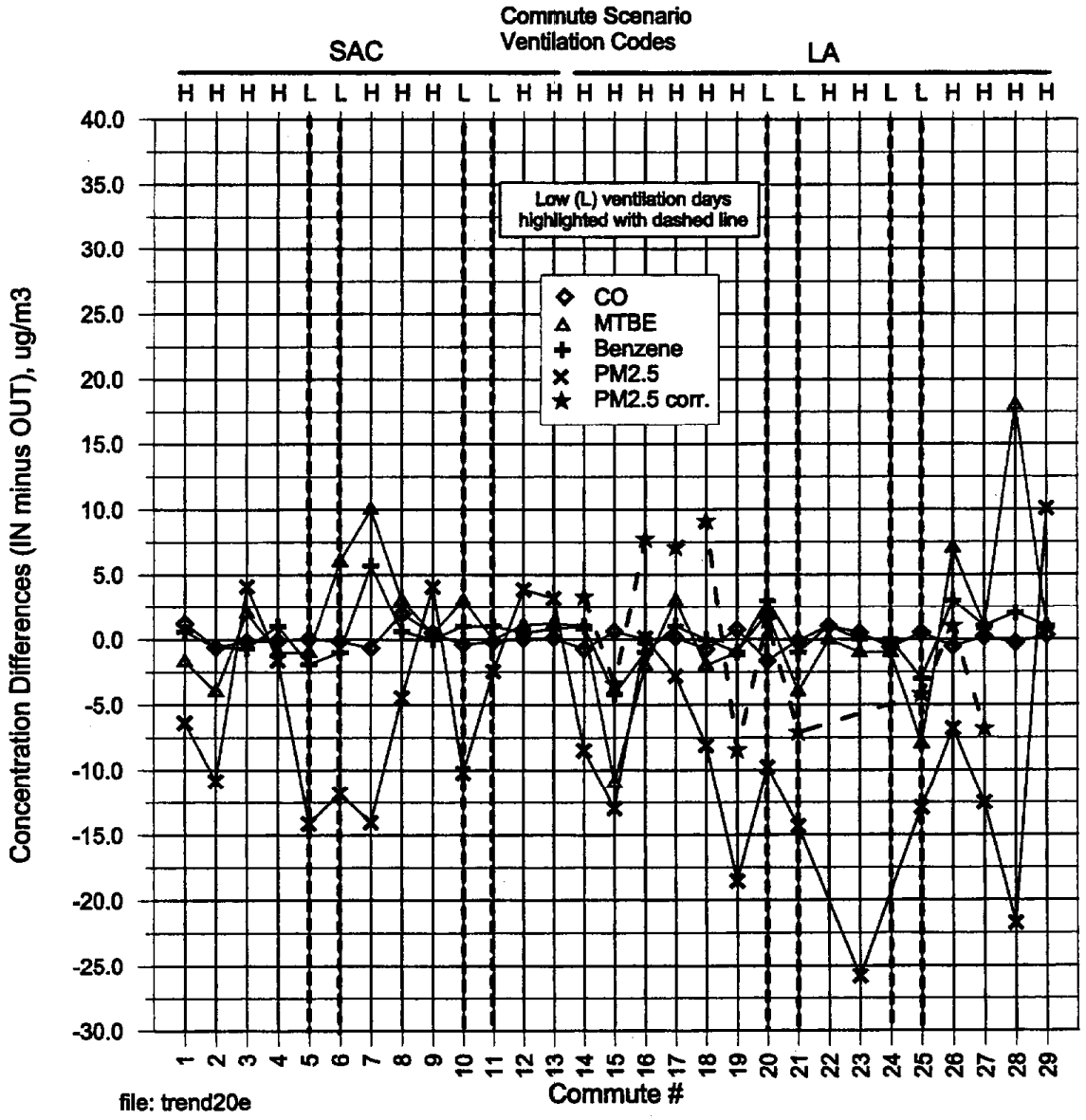
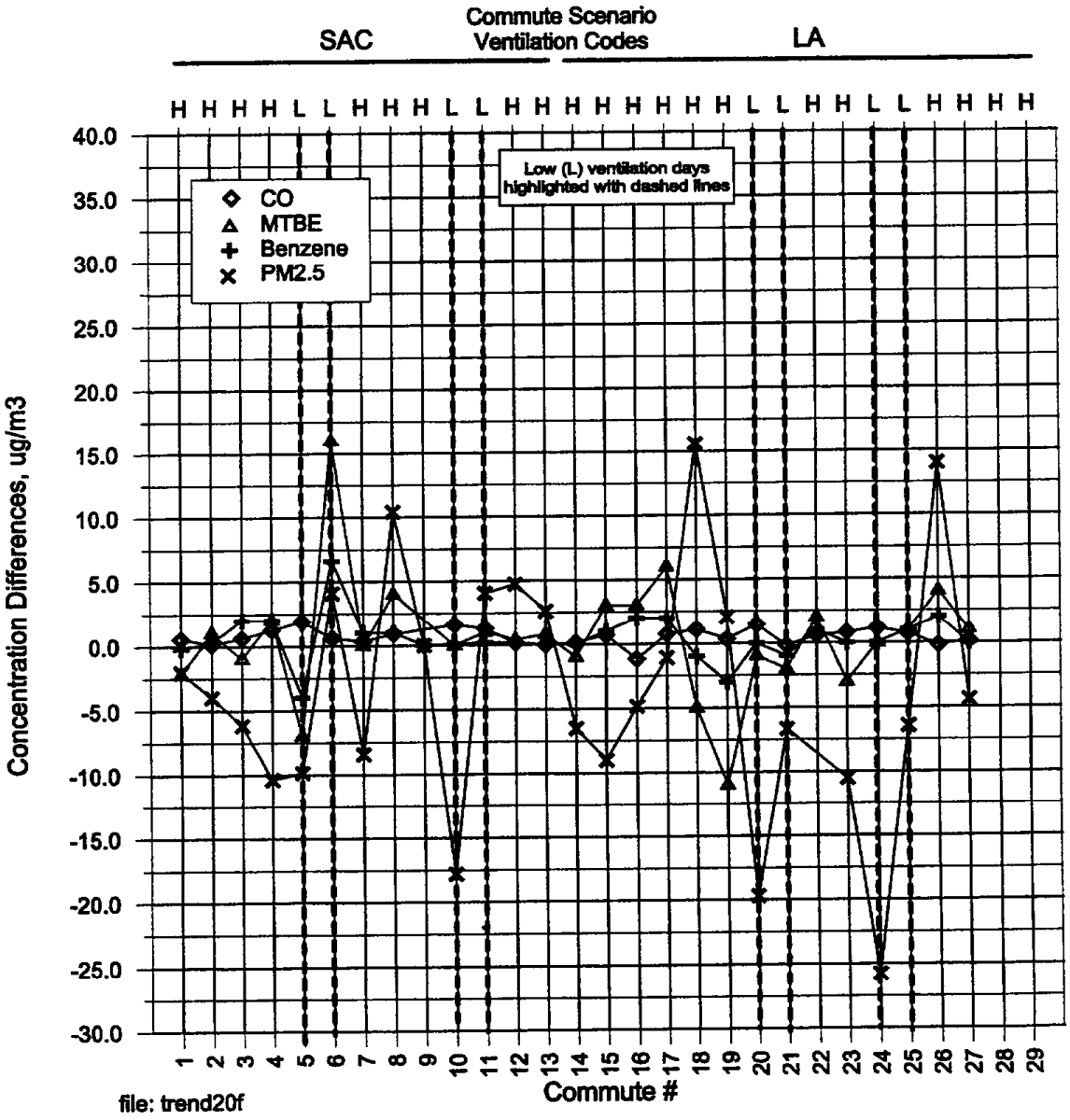


Figure 4-2. Differences Between Inside and Outside Concentration by Vehicle Ventilation Setting for Vehicle 2



4.2.2 Vehicle Type Influence (Sedans and SUV)

Tables 4-2 (A, B and C) summarize the concentration data for non-special commutes for all measures focusing on the influence of vehicle type on the in-vehicle concentration levels. Mean values for IN 1, IN 2, OUT 1, and OUT 2 were computed for Sacramento and Los Angeles, not corrected for ambient background, for each commute. Vehicle 1 was the same in both cities. Similar to the previous section for ventilation influences, the differences between the inside and outside values were computed for each vehicle and given in columns (A) and (B) to give (IN 1 - IN 2) and (OUT 1 - OUT 2). As previously noted, Vehicle 1 is the 1991 Chevrolet Caprice (sedan) in both cities. Vehicle 2 is a 1997 Ford Taurus (sedan) in Sacramento, and a 1997 Ford Explorer (SUV) in Los Angeles. Again, the (IN 1 - OUT 1) column would be expected to be the same between cities for all measurement, especially since there appeared to be no influence of vent setting on penetration. Although the data might suggest that some differences do exist between the two cities [the outside being larger than the inside more in Los Angeles than Sacramento for most of the VOC's], the differences are smaller an probably within the experimental error.

In order to evaluate the differences between Vehicle 1 and both Vehicle 2's, the IN 1 - IN 2 column was computed. The presumption is that the sources of the pollutants being addressed are external to the vehicles. Interior sources (or sinks) would confound such an analysis. This column suggests differenceminimal differences between the vehicles in Sacramento or Los Angeles for all pollutants except $PM_{2.5}$ mass. This difference is possibly attributed to a smaller particle loss rate between the outside and inside for Vehicle 1. The last column is the difference between outside concentrations for the two vehicles (OUT 1 - OUT 2). This term was computed to determine if Vehicle 2's position trailing Vehicle 1 showed the potential for lower concentrations. Only acetonitrile and carbon monoxide are negative (OUT 2 > OUT 1) for both cities. Although this may suggest that Vehicle 1 may have been a (weak) source for these pollutants, it is more likely that the CO differences are within the experimental error, and the acetonitrile values may have been cross-contaminated from the DNPH cartridges. Positive differences for both cities for $PM_{2.5}$ suggest that the emissions from the target vehicles immediately in front of Vehicle 1 were higher due to proximity. The air exchange rate data (Figure 3-6) suggest that the Explorer could provide some "insulating" effect at very low speeds, as compared to either the Caprice or the Ford Taurus (used in Sacramento). This could not be definitively established, however, given the limited number of low speed commutes. Both the newer Explorer and Taurus were intuitively expected to be more "airtight" than the older Caprice. During this study, the ranges of average commute speeds between cities were not substantial. In general, there appeared to be only a weak dependence (if any) of in-vehicle pollutant concentrations on vehicle type, except perhaps for $PM_{2.5}$. The differences between Vehicle 1 and Vehicle 2 were somewhat masked, however, by the higher pollutant "exposure" of Vehicle 1 from being closer to the exhausts of the "target" vehicles [see OUT 1 - OUT 2 column].

Table 4-2A. Influence of Vehicle Type on Organic Commute-Average Concentration Data

			Concentrations (not corrected for Ambient) in Measure Units						
Measure	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	IN 1 mean - OUT 1 mean	IN 1 mean - IN 2 mean	OUT 1 mean - OUT 2 mean
Isobutylene	Sac	2.1	10.0	9.8	9.4	8.5	0.6	0.2	0.9
µg/m3	LA	5.1	17.9	16.9	18.2	16.8	-0.4	1.0	1.4
1,3-Butadiene	Sac	0.3	2.6	2.1	2.4	2.0	0.2	0.5	0.4
µg/m3	LA	0.5	3.7	3.1	3.7	3.1	-0.1	0.6	0.6
Acetonitrile	Sac	37.3	125.2	165.1	1.9	89.6	123.3	-39.9	-87.7
µg/m3	LA	19.7	133.4	166.8	3.7	100.6	129.7	-33.4	-96.9
DCM	Sac	2.6	1.4	1.4	1.3	2.0	0.1	0.0	-0.7
µg/m3	LA	5.6	2.9	3.2	3.1	3.2	-0.2	-0.3	0.0
MTBE	Sac	4.4	23.5	19.4	21.7	18.1	1.7	4.0	3.7
µg/m3	LA	14.7	41.5	35.2	42.7	35.8	-1.2	6.2	6.9
ETBE	Sac	0.4	0.1	0.2	0.2	0.4	0.0	0.0	-0.2
µg/m3	LA	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TCFM	Sac	2.9	4.8	2.7	2.5	3.3	2.4	2.1	-0.8
µg/m3	LA	1.7	1.6	1.7	1.7	1.7	-0.1	-0.1	0.0
Benzene	Sac	1.9	10.3	11.5	9.8	10.7	0.5	-1.2	-0.9
µg/m3	LA	4.0	14.8	13.7	14.9	13.6	-0.1	1.1	1.3
Toluene	Sac	6.3	29.6	23.9	22.7	23.1	6.9	5.7	-0.4
µg/m3	LA	20.1	37.5	31.4	37.1	32.3	0.5	6.1	4.7
Ethylbenzene	Sac	1.6	6.0	4.8	4.9	4.6	1.1	1.3	0.3
µg/m3	LA	2.2	7.8	6.1	7.6	6.2	0.2	1.7	1.4
M,P-Xylene	Sac	3.4	24.8	18.6	19.0	17.4	5.8	6.2	1.6
µg/m3	LA	6.7	29.4	22.8	28.9	23.3	0.6	6.6	5.6
O-Xylene	Sac	1.7	8.5	6.5	6.7	6.3	1.8	2.0	0.4
µg/m3	LA	2.7	10.5	8.3	10.4	8.4	0.1	2.1	2.0
Formaldehyde	Sac	4.0	11.1	11.3	na	na	na	-0.2	na
µg/m3	LA	12.4	16.5	16.4	na	na	na	0.1	na

Notes: a Expected n value for Sacramento is: (10)
Expected n value for Los Angeles is (12)
b Values are ug/m3, unless noted otherwise in measure column
c Vehicle 1 (IN 1 and OUT 1) is 1991 Chevrolet Caprice for SAC and LA
d Vehicle 2 (IN 2 and OUT 2) is 1997 Ford Taurus in SAC and 1997 Ford Explorer in LA
e Special study commutes (Rural, School Bus, Carpool, and Max. Concentration) data not included
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-2B. Influence of Vehicle Type on Continuous Commute-Average Concentration Data

			Measures in specified units						
Measure	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	IN 1 mean - OUT 1 mean	IN 1 mean - IN 2 mean	OUT 1 mean - OUT 2 mean
CO Avg	Sac	0.0	2.0	3.2	2.4	4.1	-0.4	-1.2	-1.7
(ppm)	LA	0.5	4.5	4.8	4.7	5.2	-0.2	-0.2	-0.5
CO Peak	Sac	0.3	11.1	15.2	16.4	18.3	-5.3	-4.1	-1.9
(ppm)	LA	1.4	27.5	12.3	36.1	15.9	-8.6	15.3	20.2
Black Carbon	Sac	NA	4.8	na	5.2	na	-0.4	na	na
µg/m3	LA	NA	10.5	na	15.2	na	-4.7	na	na
LASX	Sac	NA	707	na	1,548	na	-841.0	na	na
particles/cm3	LA	NA	3,159	na	6,391	na	-3232.8	na	na

Notes: a Expected n value for Sacramento is: (10)
Expected n value for Los Angeles is (12)
b Values are ug/m3, unless noted otherwise in measure column
c Vehicle 1 (IN 1 and OUT 1) is 1991 Chevrolet Caprice for SAC and LA
d Vehicle 2 (IN 2 and OUT 2) is 1997 Ford Taurus in SAC and 1997 Ford Explorer in LA
e Special study commutes (Rural, School Bus, Carpool, and Max. Concentration) data not included
Ambient data not available to correct black carbon or LAS-X data
LAS-X OUT data corrected for sampling line losses
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-2C. Influence of Vehicle Type on PM2.5 & PM10 Commute-Average Concentration Data

			Concentrations (not corrected for Ambient) in Measure Units						
Measure	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	IN 1 mean - OUT 1 mean	IN 1 mean - IN 2 mean	OUT 1 mean - OUT 2 mean
PM 10 mass	Sac	23.1	24.6	10.9	na	na	na	na	na
µg/m3	LA	71.1	56.2	49.4	na	na	na	na	na
PM 2.5 mass	Sac	8.7	12.6	9.0	19.8	13.0	-7.2	3.6	6.8
µg/m3	LA	42.8	48.9	38.5	62.8	42.9	-13.9	10.4	19.9
PM10 Cd	Sac	0.07	0.04	0.05	na	na	na	na	na
µg/m3	LA	0.04	0.05	0.03	na	na	na	na	na
PM10 Cr	Sac	0.03	0.02	0.02	na	na	na	na	na
µg/m3	LA	0.02	0.01	0.01	na	na	na	na	na
PM10 Mn	Sac	0.03	0.03	0.01	na	na	na	na	na
µg/m3	LA	0.01	0.01	0.01	na	na	na	na	na
PM10 Ni	Sac	0.01	0.01	0.01	na	na	na	na	na
µg/m3	LA	0.01	0.01	0.01	na	na	na	na	na
PM10 Pb	Sac	0.01	0.03	0.01	na	na	na	na	na
µg/m3	LA	0.01	0.01	0.01	na	na	na	na	na
PM10 S	Sac	0.50	0.46	0.33	na	na	na	na	na
µg/m3	LA	2.38	1.88	1.85	na	na	na	na	na
PM2.5 Cd	Sac	0.03	0.05	0.06	0.04	0.02	0.0	0.0	0.0
µg/m3	LA	0.03	0.02	0.05	0.05	0.04	0.0	0.0	0.0
PM2.5 Cr	Sac	0.01	0.02	0.02	0.01	0.01	0.0	0.0	0.0
µg/m3	LA	0.02	0.02	0.01	0.01	0.01	0.0	0.0	0.0
PM2.5 Mn	Sac	0.01	0.01	0.02	0.02	0.01	0.0	0.0	0.0
µg/m3	LA	0.01	0.01	0.01	0.01	0.00	0.0	0.0	0.0
PM2.5 Ni	Sac	0.00	0.01	0.00	0.01	0.01	0.0	0.0	0.0
µg/m3	LA	0.01	0.01	0.01	0.01	0.01	0.0	0.0	0.0
PM2.5 Pb	Sac	0.01	0.02	0.02	0.03	0.02	0.0	0.0	0.0
µg/m3	LA	0.01	0.01	0.01	0.02	0.01	0.0	0.0	0.0
PM2.5 S	Sac	0.44	0.44	0.31	0.48	0.40	0.0	0.1	0.1
µg/m3	LA	2.09	1.81	1.64	2.07	1.76	-0.3	0.2	0.3

Notes: a Expected n value for Sacramento is: (10)
Expected n value for Los Angeles is (12)
b Values are ug/m3, unless noted otherwise in measure column
c Vehicle 1 (IN 1 and OUT 1) is 1991 Chevrolet Caprice for SAC and LA
d Vehicle 2 (IN 2 and OUT 2) is 1997 Ford Taurus in SAC and 1997 Ford Explorer in LA
e Special study commutes (Rural, School Bus, Carpool, and Max. Concentration) data not included
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-2D. Influence of Vehicle Type on Commute-Average Associated Measures

			Measures in specified units						
Measure	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	IN 1 mean - OUT 1 mean	IN 1 mean - IN 2 mean	OUT 1 mean - OUT 2 mean
Speed (mph)	Sac	na	32.3	na	na	na	na	na	na
	LA	na	33.2	na	na	na	na	na	na
Spacing Range (feet)	Sac	na	75.4	na	na	na	na	na	na
	LA	na	52.1	na	na	na	na	na	na
Level of Congestion (unitless)	Sac	na	3.0	na	na	na	na	na	na
	LA	na	2.9	na	na	na	na	na	na
Miles Traveled	Sac	na	66.8	na	na	na	na	na	na
	LA	na	67.9	na	na	na	na	na	na
Heavy Duty Diesel Influence, %	Sac	na	41%	na	na	na	na	na	na
	LA	na	36%	na	na	na	na	na	na

Notes:

a Expected n value for Sacramento is: (10)
Expected n value for Los Angeles is (12)

b Values are ug/m3, unless noted otherwise in measure column

c Vehicle 1 (IN 1 and OUT 1) is 1991 Chevrolet Caprice for SAC and LA

d Vehicle 2 (IN 2 and OUT 2) is 1997 Ford Taurus in SAC and 1997 Ford Explorer in LA

e Special study commutes (Rural, School Bus, Carpool, and Max. Concentration) data not included

na Not Available (no samples scheduled)

AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2

ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

4.2.3 Roadway Type Influence (Freeway and Arterial)

Tables 4-3 (A thru E) summarize the concentration data for non-special commutes for all measures focusing on the influence of roadway type on the in-vehicle concentration levels. Mean values for IN 1, IN 2, OUT 1, and OUT 2 were stratified by freeway and arterial commutes and computed for Sacramento and Los Angeles. The concentrations were corrected for ambient background, for each commute. To focus on the in-vehicle concentration influences for the Caprice, differences were computed between the scenario means as given in the last two columns for Car 1 and Car 2.

The larger metropolitan area and associated higher traffic densities in Los Angeles would suggest that the LA means should be significantly higher than those from Sacramento in almost all cases. For MTBE, this was true for both freeway and arterial commutes. A similar trend was noted for benzene. The data for MTBE and benzene also suggest that both Sacramento and LA commutes produced higher IN 1 concentrations for arterial roadways, as compared to freeways. This was reversed, however, for IN 2, suggesting that additional (unmeasured) factors including the spacing between Car 1 and Car 2 may have been different for the two roadway types. A partial explanation for the difference for Car 1, may be the substantial diesel "influence" from target vehicle trailing in Los Angeles (see Table 4-3E). Following diesel vehicles (which generate no MTBE and undoubtedly induce greater mixing from turbulence) 50 % and 82 % of the time on freeways (as compared to 4 % and 2 % on arterial roadways), could significantly reduce the MTBE concentrations in the trailing vehicle [while increasing the concentrations of diesel-associated pollutants]. This could also help to explain the similar trends for many of the other VOC's. CO shows a similar trend to target VOC's. This is reasonable, since gasoline powered vehicles could be expected to generate greater quantities of CO than diesels, while diesels generate greater quantities of black carbon and particles. The particle issue is complex, however, in that the substantial turbulence behind larger vehicle, may periodically re-entrain some larger particles that fall within the <10 μm size range. Additionally, the ambient $PM_{2.5}$ and PM_{10} concentrations were substantial compared to the differences observed. The black carbon and particle count data suggest that LA is substantially higher for both measures, however, there were no ambient data available to use to correct the concentration data. The $PM_{2.5}$ and PM_{10} sulfur (background-corrected) data suggest that the LA and freeway particle concentration data are higher, but the differences were very small compared to the ambient levels. While LA formaldehyde levels were generally higher in LA, compared to Sacramento, the Sacramento in-vehicle levels for the arterial commutes were significantly higher than for LA.

A review of the vehicular data in Table 4-3E (Scenario Comparison for Car 1) shows that the miles traveled per commute were significantly higher in LA for the arterial commute at significantly higher speeds. The spacing between vehicles in LA was significantly closer than those in Sacramento. Arterial vehicle spacing was somewhat higher than freeway. The levels of traffic congestion were similar in LA and Sacramento for freeway and arterial roadways, with the freeway congestion somewhat higher than the arterial. The influence of roadway type on concentrations, comparing Sacramento and Los Angeles, appears to be significant for selected driving scenarios, but is affected by a number of complicating factors. The location (LA or Sacramento) appears to be the most important factor. The driving protocol focus on diesel vehicles also contributed to the difficulty in detecting consistent trends associated with roadway type.

Table 4-3A. Influence of Roadway Type on Organic Commute-Average Concentrations

				Concentrations (corrected for Ambient) in Measure Units						
	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
Isobutylene	FR	Sac	1.9	8.5	10.5	8.3	7.7	Freeway: Sac - LA	-2.8	-2.0
µg/m3		LA	5.2	11.3	12.5	12.5	12.0	Arterial: Sac - LA	2.4	-5.5
	AR	Sac	2.7	8.9	6.8	7.7	6.5	Sac: Freeway - Arterial	-4.4	3.7
		LA	4.3	13.3	12.3	12.9	11.5	LA: Freeway - Arterial	10.7	0.2
1,3-Butadiene	FR	Sac	0.1	2.6	2.7	2.7	2.2	Freeway: Sac - LA	-0.5	-0.3
µg/m3		LA	0.7	3.1	3.0	3.4	3.0	Arterial: Sac - LA	-0.7	-1.1
	AR	Sac	0.5	2.3	1.2	1.9	1.5	Sac: Freeway - Arterial	0.3	1.5
		LA	0.4	3.0	2.3	3.0	2.3	LA: Freeway - Arterial	0.1	0.7
Acetonitrile	FR	Sac	45.3	71.4	177.2	-43.5	62.5	Freeway: Sac - LA	-59.4	15.8
µg/m3		LA	19.9	130.8	161.4	-14.1	76.9	Arterial: Sac - LA	-37.6	-113.8
	AR	Sac	36.7	137.4	133.5	-34.7	57.6	Sac: Freeway - Arterial	-66.0	43.7
		LA	30.1	175.0	247.3	-27.9	138.1	LA: Freeway - Arterial	-44.2	-85.9
DCM	FR	Sac	1.9	-0.9	-0.2	-0.8	0.0	Freeway: Sac - LA	-0.6	-0.3
µg/m3		LA	3.0	-0.3	0.0	0.3	0.1	Arterial: Sac - LA	-1.4	-2.4
	AR	Sac	4.1	-1.9	-2.5	-2.4	-1.5	Sac: Freeway - Arterial	1.0	2.2
		LA	3.6	-0.5	-0.1	-0.5	-0.4	LA: Freeway - Arterial	0.2	0.1
MTBE	FR	Sac	3.2	19.8	17.7	18.0	15.4	Freeway: Sac - LA	-4.4	-5.3
µg/m3		LA	13.5	24.3	23.0	28.0	22.9	Arterial: Sac - LA	-2.7	-5.6
	AR	Sac	6.7	23.6	15.3	19.8	14.0	Sac: Freeway - Arterial	-3.8	2.4
		LA	9.7	26.3	20.9	26.4	19.6	LA: Freeway - Arterial	-2.0	2.1
ETBE	FR	Sac	0.1	0.0	-0.1	-0.1	-0.1	Freeway: Sac - LA	0.0	0.0
µg/m3		LA	0.1	-0.1	-0.1	-0.1	-0.1	Arterial: Sac - LA	-0.6	-0.5
	AR	Sac	0.8	-0.6	-0.5	-0.4	0.1	Sac: Freeway - Arterial	0.5	0.4
		LA	0.0	0.0	0.0	0.0	0.0	LA: Freeway - Arterial	-0.1	-0.1
TCFM	FR	Sac	2.2	0.2	0.8	0.1	0.6	Freeway: Sac - LA	0.4	0.9
µg/m3		LA	1.8	-0.2	-0.1	0.1	-0.1	Arterial: Sac - LA	4.9	-1.1
	AR	Sac	4.2	4.7	-1.2	-1.2	0.5	Sac: Freeway - Arterial	-4.5	2.0
		LA	1.7	-0.2	-0.1	-0.2	-0.2	LA: Freeway - Arterial	0.0	0.0
Benzene	FR	Sac	1.4	8.9	12.5	9.8	10.9	Freeway: Sac - LA	-1.5	1.0
µg/m3		LA	4.0	10.4	11.5	11.0	11.1	Arterial: Sac - LA	-2.4	-1.3
	AR	Sac	2.9	9.2	8.4	7.1	8.0	Sac: Freeway - Arterial	-0.4	4.1
		LA	2.8	11.7	9.7	11.7	9.2	LA: Freeway - Arterial	-1.3	1.8
Toluene	FR	Sac	4.6	27.3	22.9	19.5	20.6	Freeway: Sac - LA	12.3	10.7
µg/m3		LA	19.0	15.0	12.2	15.4	12.9	Arterial: Sac - LA	-0.2	-4.2
	AR	Sac	8.2	27.1	16.2	17.2	15.1	Sac: Freeway - Arterial	0.2	6.7
		LA	9.6	27.4	20.5	26.4	20.1	LA: Freeway - Arterial	-12.4	-8.2
Ethylbenzene	FR	Sac	0.7	4.8	4.3	3.9	3.8	Freeway: Sac - LA	-0.4	0.3
µg/m3		LA	2.2	5.2	4.0	5.0	4.0	Arterial: Sac - LA	0.4	-0.2
	AR	Sac	1.8	6.3	3.9	4.6	3.9	Sac: Freeway - Arterial	-1.6	0.4
		LA	1.6	5.9	4.1	5.6	4.1	LA: Freeway - Arterial	-0.7	-0.1
M,P-Xylene	FR	Sac	2.7	22.0	18.4	16.7	16.1	Freeway: Sac - LA	1.3	2.3
µg/m3		LA	7.4	20.8	16.0	20.3	16.5	Arterial: Sac - LA	2.5	-2.2
	AR	Sac	5.0	26.0	14.9	17.7	14.3	Sac: Freeway - Arterial	-4.0	3.5
		LA	5.3	23.6	17.1	23.3	17.1	LA: Freeway - Arterial	-2.8	-1.1
O-Xylene	FR	Sac	1.5	6.9	5.7	5.2	5.1	Freeway: Sac - LA	-0.3	0.0
µg/m3		LA	2.8	7.2	5.7	7.1	5.8	Arterial: Sac - LA	0.3	-1.3
	AR	Sac	2.3	8.4	4.8	6.0	5.1	Sac: Freeway - Arterial	-1.5	0.8
		LA	2.0	8.1	6.2	8.1	6.1	LA: Freeway - Arterial	-0.9	-0.5
Formaldehyde	FR	Sac	4.0	7.2	10.0	na	na	Freeway: Sac - LA	6.0	1.2
µg/m3		LA	6.7	7.7	8.8	na	na	Arterial: Sac - LA	2.1	2.4
	AR	Sac	4.1	8.1	8.5	na	na	Sac: Freeway - Arterial	-0.5	1.5
		LA	9.7	5.7	6.1	na	na	LA: Freeway - Arterial	-0.4	2.7

Note: a Expected n values for Sacramento are: FR (4), AR (4)
Expected n values for Los Angeles are: FR (4), AR (4)
b Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-3B. Influence of Roadway Type on Continuous Commute-Average Concentration Data

			Concentrations (corrected for Ambient) in Measure Units						
	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
CO Avg (ppm)	FR	Sac	0.0	2.1	3.1	2.2	4.2	Freeway: Sac - LA	-2.5	-1.8
		LA	0.5	4.6	4.9	4.9	5.1	Arterial: Sac - LA	-2.0	-1.4
	AR	Sac	0.0	2.3	3.0	2.7	4.1	Sac: Freeway - Arterial	-0.2	0.1
		LA	0.0	4.2	4.4	4.3	4.8	LA: Freeway - Arterial	0.3	0.5
CO Peak (ppm)	FR	Sac	0.0	10.5	22.3	11.5	25.8	Freeway: Sac - LA	-22.3	10.8
		LA	1.3	32.8	11.5	30.3	13.5	Arterial: Sac - LA	-12.8	0.3
	AR	Sac	0.8	10.0	8.8	22.7	12.8	Sac: Freeway - Arterial	0.5	13.5
		LA	0.5	22.8	8.5	39.8	14.0	LA: Freeway - Arterial	10.0	3.0
Black Carbon µg/m3	FR	Sac	na	6.7	na	7.9	na	Freeway: Sac - LA	-3.7	na
		LA	na	10.4	na	17.7	na	Arterial: Sac - LA	-18.4	na
	AR	Sac	na	1.3	na	3.1	na	Sac: Freeway - Arterial	5.5	na
		LA	na	19.7	na	17.4	na	LA: Freeway - Arterial	-9.3	na
LASX particle counts/cm3	FR	Sac	na	759	na	1,942	na	Freeway: Sac - LA	-2202	na
		LA	na	2,960	na	6,724	na	Arterial: Sac - LA	-2656	na
	AR	Sac	na	33	na	139	na	Sac: Freeway - Arterial	725	na
		LA	na	2,690	na	5,170	na	LA: Freeway - Arterial	271	na

Note: a Expected n values for Sacramento are: FR (4), AR (4)
Expected n values for Los Angeles are: FR (4), AR (4)
b Values are ug/m3, unless noted otherwise in measure column
Ambient data not available to correct black carbon or LAS-X data
LAS-X OUT data corrected for sampling line losses
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-3C. Influence of Roadway Type on PM10 Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units						
	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
PM 10 mass	FR	Sac	22.7	7.5	-12.7	na	na	Freeway: Sac - LA	12.2	10.7
µg/m3		LA	59.5	-4.7	-23.3	na	na	Arterial: Sac - LA	27.8	15.5
	AR	Sac	20.3	-3.9	-10.3	na	na	Sac: Freeway - Arterial	11.4	-2.3
		LA	77.3	-31.7	-25.9	na	na	LA: Freeway - Arterial	27.0	2.5
PM10 Cd	FR	Sac	0.10	0.00	0.00	na	na	Freeway: Sac - LA	-0.02	-0.01
µg/m3		LA	0.10	0.02	0.01	na	na	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.10	0.00	0.00	na	na	Sac: Freeway - Arterial	0.00	0.00
		LA	0.10	0.00	0.00	na	na	LA: Freeway - Arterial	0.02	0.01
PM10 Cr	FR	Sac	0.40	0.00	0.00	na	na	Freeway: Sac - LA	0.00	0.00
µg/m3		LA	0.40	0.00	0.00	na	na	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.40	0.00	0.00	na	na	Sac: Freeway - Arterial	0.00	0.00
		LA	0.40	0.00	0.00	na	na	LA: Freeway - Arterial	0.00	0.00
PM10 Mn	FR	Sac	0.04	0.00	0.00	na	na	Freeway: Sac - LA	0.00	0.00
µg/m3		LA	0.04	0.00	0.00	na	na	Arterial: Sac - LA	0.01	0.00
	AR	Sac	0.04	0.01	0.00	na	na	Sac: Freeway - Arterial	-0.01	0.00
		LA	0.04	0.00	0.00	na	na	LA: Freeway - Arterial	0.00	0.00
PM10 Ni	FR	Sac	0.03	0.00	0.00	na	na	Freeway: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	na	na	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.03	0.00	0.00	na	na	Sac: Freeway - Arterial	0.00	0.00
		LA	0.03	0.00	0.00	na	na	LA: Freeway - Arterial	0.00	0.00
PM10 Pb	FR	Sac	0.03	0.00	0.00	na	na	Freeway: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	na	na	Arterial: Sac - LA	0.01	0.00
	AR	Sac	0.03	0.01	0.00	na	na	Sac: Freeway - Arterial	-0.01	0.00
		LA	0.03	0.00	0.00	na	na	LA: Freeway - Arterial	0.00	0.00
PM10 S	FR	Sac	0.48	-0.01	-0.19	na	na	Freeway: Sac - LA	0.21	0.27
µg/m3		LA	1.56	-0.23	-0.46	na	na	Arterial: Sac - LA	0.93	0.70
	AR	Sac	0.44	-0.07	-0.16	na	na	Sac: Freeway - Arterial	0.05	-0.03
		LA	3.62	-0.99	-0.85	na	na	LA: Freeway - Arterial	0.77	0.39

Note: a Expected n values for Sacramento are: FR (4), AR (4)
Expected n values for Los Angeles are: FR (4), AR (4)
b Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-3D. Influence of Roadway Type on PM2.5 Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units						
	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
PM 2.5 mass µg/m3	FR	Sac	6.3	8.2	0.2	14.2	6.7	Freeway: Sac - LA	-4.1	0.3
		LA	32.1	12.3	-0.1	21.6	10.0	Arterial: Sac - LA	6.0	14.5
	AR	Sac	10.6	-1.0	-0.6	6.8	2.4	Sac: Freeway - Arterial	9.2	0.8
		LA	48.0	-7.0	-15.1	16.0	-9.4	LA: Freeway - Arterial	19.3	15.0
PM2.5 Cd µg/m3	FR	Sac	0.10	0.00	0.00	0.00	0.00	Freeway: Sac - LA	0.00	0.00
		LA	0.10	0.00	0.00	0.00	0.00	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.10	0.00	0.00	0.00	0.00	Sac: Freeway - Arterial	0.00	0.00
		LA	0.10	0.00	0.00	0.00	0.00	LA: Freeway - Arterial	0.00	0.00
PM2.5 Cr µg/m3	FR	Sac	0.10	0.00	0.00	0.00	0.00	Freeway: Sac - LA	0.00	0.00
		LA	0.10	0.00	0.00	0.00	0.00	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.10	0.00	0.00	0.00	0.00	Sac: Freeway - Arterial	0.00	0.00
		LA	0.10	0.00	0.00	0.00	0.00	LA: Freeway - Arterial	0.00	0.00
PM2.5 Mn µg/m3	FR	Sac	0.35	-0.08	0.02	0.08	0.01	Freeway: Sac - LA	-0.08	0.02
		LA	0.35	0.00	0.00	0.01	0.00	Arterial: Sac - LA	-0.08	0.00
	AR	Sac	0.35	-0.08	0.00	-0.07	0.00	Sac: Freeway - Arterial	0.00	0.02
		LA	0.35	0.00	0.00	0.00	0.00	LA: Freeway - Arterial	0.00	0.00
PM2.5 Ni µg/m3	FR	Sac	0.03	0.01	0.00	0.00	0.00	Freeway: Sac - LA	0.01	0.00
		LA	0.03	0.00	0.00	0.00	0.00	Arterial: Sac - LA	0.00	0.00
	AR	Sac	0.03	0.00	0.00	0.00	0.00	Sac: Freeway - Arterial	0.01	0.00
		LA	0.03	0.00	0.00	0.00	0.01	LA: Freeway - Arterial	0.00	0.00
PM2.5 Pb µg/m3	FR	Sac	0.03	0.01	0.01	0.02	0.00	Freeway: Sac - LA	0.01	0.01
		LA	0.03	0.01	0.00	0.00	0.00	Arterial: Sac - LA	0.00	0.01
	AR	Sac	0.03	0.01	0.01	0.03	0.01	Sac: Freeway - Arterial	0.00	0.00
		LA	0.03	0.01	0.00	0.00	0.00	LA: Freeway - Arterial	0.00	0.00
PM2.5 S µg/m3	FR	Sac	0.40	0.02	-0.11	0.06	-0.02	Freeway: Sac - LA	0.03	0.05
		LA	1.34	-0.01	-0.16	0.08	-0.09	Arterial: Sac - LA	0.60	0.64
	AR	Sac	0.39	-0.06	-0.18	0.00	-0.13	Sac: Freeway - Arterial	0.08	0.08
		LA	3.09	-0.66	-0.82	-0.07	-0.49	LA: Freeway - Arterial	0.65	0.66

Note: a Expected n values for Sacramento are: FR (4), AR (4)
Expected n values for Los Angeles are: FR (4), AR (4)
b Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-3E. Influence of Roadway Type on Commute-Average Associated Measures

				Concentrations (corrected for Ambient) in Measure Units						
	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Scenario Comparisons:	Car 1	Car 2
Speed	FR	Sac	na	32.5	na	na	na	Freeway: Sac - LA	-9.6	na
(mph)		LA	na	42.1	na	na	na	Arterial: Sac - LA	2.1	na
	AR	Sac	na	23.8	na	na	na	Sac: Freeway - Arterial	8.7	na
		LA	na	21.7	na	na	na	LA: Freeway - Arterial	20.4	na
Spacing	FR	Sac	na	68.9	na	na	na	Freeway: Sac - LA	18.5	na
Range		LA	na	50.4	na	na	na	Arterial: Sac - LA	19.2	na
(fee)	AR	Sac	na	74.4	na	na	na	Sac: Freeway - Arterial	-5.5	na
		LA	na	55.2	na	na	na	LA: Freeway - Arterial	-4.7	na
Level of	FR	Sac	na	3.9	na	na	na	Freeway: Sac - LA	0.5	na
Congestion		LA	na	3.3	na	na	na	Arterial: Sac - LA	-0.2	na
(unitless)	AR	Sac	na	2.5	na	na	na	Sac: Freeway - Arterial	1.4	na
		LA	na	2.7	na	na	na	LA: Freeway - Arterial	0.6	na
Miles Traveled	FR	Sac	na	68.3	na	na	na	Freeway: Sac - LA	-15.9	na
		LA	na	84.2	na	na	na	Arterial: Sac - LA	6.1	na
	AR	Sac	na	49.1	na	na	na	Sac: Freeway - Arterial	19.2	na
		LA	na	43.0	na	na	na	LA: Freeway - Arterial	41.2	na
Heavy Duty	FR	Sac	na	50%	na	na	na	Freeway: Sac - LA	-26%	na
Diesel		LA	na	82%	na	na	na	Arterial: Sac - LA	2%	na
Influence	AR	Sac	na	4%	na	na	na	Sac: Freeway - Arterial	52%	na
(% of commute)		LA	na	2%	na	na	na	LA: Freeway - Arterial	80%	na

Note: a Expected n values for Sacramento are: FR (4), AR (4)
Expected n values for Los Angeles are: FR (4), AR (4)
b Values are ug/m3, unless noted otherwise in measure column
a Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

4.2.4 Freeway Congestion Influence (Rush and Non-Rush)

Tables 4-4 (A thru E) summarize the concentration data for non-special commutes for all measures focusing on the influence of freeway congestion level on the in-vehicle concentration levels. Mean values for ambient-corrected IN 1, IN 2, OUT 1, and OUT 2 were stratified by freeway rush (FR) and freeway non-rush (FNR) commutes and computed for Sacramento and Los Angeles. To focus on the in-vehicle concentration influences for the Caprice, differences were computed between city and scenario means as given in the last column.

Intuitively, Los Angeles rush periods might be expected to be higher than those for Sacramento for freeway rush and freeway non-rush periods, given the larger freeways and greater traffic volumes. Similarly, freeway rush would be expected to be higher than freeway non-rush periods. The traffic measures in Table 4-4E show that these expectations are generally consistent for most of the freeway-generated pollutants measured. The LA freeway rush commutes produced significantly higher in-vehicle concentrations for MTBE, benzene, $PM_{2.5}$, and CO, than did the Sacramento commutes. This trend was even more pronounced for the freeway non-rush commutes (except for CO), comparing LA to Sacramento. An assessment of the general influence of freeway congestion level on in-vehicle concentrations could not be defined that applied in all cases.

While in-vehicle levels for rush commutes were higher in Sacramento compared to non-rush, the reverse appeared to be true in Los Angeles for MTBE, benzene, and $PM_{2.5}$. Closer inspection of the individual commute data, however, showed that single, unusual commutes had strong influences on the commute averages. Both the MTBE and benzene IN1 Rush levels in LA for 9/26 AM were relatively low, while the $PM_{2.5}$ IN1 Non-Rush level for 9/25 AM was relatively high. The undue influence of these single values suggests that the limited data set is too small and variable to be definitive. The FR commutes in LA had an unexpectedly higher speed and greater miles traveled than in Sacramento, consistent with a slightly lower Level of Congestion in LA. Even with the higher LA rush period speeds, the vehicle spacing in LA for both FR and FNR were substantially smaller. As expected, the vehicle speeds were somewhat greater during non-rush periods in both cities.

The scenario differences for MTBE, benzene, and $PM_{2.5}$ levels inside Vehicle 1 were consistently related inversely with the vehicle spacing comparisons in Table 4-4E. This consistency supports the observation that spacing to the lead vehicle is potentially an important factor in the in-vehicle concentration levels for pollutants generated on the roadway, and even more important if the lead vehicle is a significant source. This observation was less consistent for those pollutants with significant non-vehicular sources. Similar analyses were impossible for the pollutant measures that did not have an ambient background correction (e.g. particle count and black carbon). Although the freeway congestion level generally dictates a spacing between vehicles (spacing usually decreases as congestion increases), the driver may have some latitude in how closely leading vehicles are followed (or whether to change to a different lane position). In general, the Freeway Rush commutes did appear to show higher background-corrected in-vehicle concentrations than did the Non-Rush commutes.

Table 4-4A. Influence of Freeway Congestion Level on Organic Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units						
Measure	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
Isobutylene	FR	Sac	1.9	8.5	10.5	8.3	7.7	Rush: Sac - LA	-2.8	-2.0
µg/m3		LA	5.2	11.3	12.5	12.5	12.0	Non-Rush: Sac - LA	-6.7	-5.1
	FNR	Sac	1.2	4.8	3.8	4.5	3.5	Sac: Rush - Non-Rush	3.7	6.7
		LA	5.8	11.5	8.9	12.0	11.3	LA: Rush - Non-Rush	-0.2	3.6
1,3-Butadiene	FR	Sac	0.1	2.6	2.7	2.7	2.2	Rush: Sac - LA	-0.5	-0.3
µg/m3		LA	0.7	3.1	3.0	3.4	3.0	Non-Rush: Sac - LA	-1.9	-1.5
	FNR	Sac	0.1	1.8	1.3	1.2	1.1	Sac: Rush - Non-Rush	0.8	1.4
		LA	0.4	3.7	2.8	3.6	3.2	LA: Rush - Non-Rush	-0.6	0.2
Acetonitrile	FR	Sac	45.3	71.4	177.2	-43.5	62.5	Rush: Sac - LA	-59.4	15.8
µg/m3		LA	19.9	130.8	161.4	-14.1	76.9	Non-Rush: Sac - LA	6.7	-18.5
	FNR	Sac	22.5	22.2	17.8	-20.6	21.5	Sac: Rush - Non-Rush	49.2	159.4
		LA	9.7	15.5	36.3	-6.2	30.1	LA: Rush - Non-Rush	115.4	125.1
DCM	FR	Sac	1.9	-0.9	-0.2	-0.8	0.0	Rush: Sac - LA	-0.6	-0.3
µg/m3		LA	3.0	-0.3	0.0	0.3	0.1	Non-Rush: Sac - LA	13.2	12.9
	FNR	Sac	1.1	-0.2	-0.3	0.0	0.2	Sac: Rush - Non-Rush	-0.7	0.1
		LA	16.9	-13.4	-13.2	-13.5	-13.3	LA: Rush - Non-Rush	13.0	13.3
MTBE	FR	Sac	3.2	19.8	17.7	18.0	15.4	Rush: Sac - LA	-4.4	-5.3
µg/m3		LA	13.5	24.3	23.0	28.0	22.9	Non-Rush: Sac - LA	-17.5	-9.7
	FNR	Sac	2.0	8.6	9.4	11.3	9.8	Sac: Rush - Non-Rush	11.2	8.3
		LA	15.3	26.1	19.1	26.4	25.1	LA: Rush - Non-Rush	-1.9	3.9
ETBE	FR	Sac	0.1	0.0	-0.1	-0.1	-0.1	Rush: Sac - LA	0.0	0.0
µg/m3		LA	0.1	-0.1	-0.1	-0.1	-0.1	Non-Rush: Sac - LA	0.1	0.1
	FNR	Sac	0.0	0.0	0.0	0.0	0.0	Sac: Rush - Non-Rush	-0.1	-0.1
		LA	0.1	-0.1	-0.1	-0.1	-0.1	LA: Rush - Non-Rush	0.0	0.0
TCFM	FR	Sac	2.2	0.2	0.8	0.1	0.6	Rush: Sac - LA	0.4	0.9
µg/m3		LA	1.8	-0.2	-0.1	0.1	-0.1	Non-Rush: Sac - LA	-0.5	-0.6
	FNR	Sac	1.8	-0.2	-0.3	-0.1	-0.2	Sac: Rush - Non-Rush	0.3	1.1
		LA	1.4	0.3	0.4	0.4	0.5	LA: Rush - Non-Rush	-0.5	-0.4
Benzene	FR	Sac	1.4	8.9	12.5	9.8	10.9	Rush: Sac - LA	-1.5	1.0
µg/m3		LA	4.0	10.4	11.5	11.0	11.1	Non-Rush: Sac - LA	-4.9	-2.3
	FNR	Sac	0.9	5.7	6.4	5.7	6.3	Sac: Rush - Non-Rush	3.2	6.1
		LA	3.9	10.6	8.6	10.6	10.1	LA: Rush - Non-Rush	-0.2	2.8
Toluene	FR	Sac	4.6	27.3	22.9	19.5	20.6	Rush: Sac - LA	12.3	10.7
µg/m3		LA	19.0	15.0	12.2	15.4	12.9	Non-Rush: Sac - LA	8.5	16.4
	FNR	Sac	5.8	7.4	9.5	8.4	12.5	Sac: Rush - Non-Rush	20.0	13.4
		LA	39.9	-1.1	-7.0	-0.7	-1.2	LA: Rush - Non-Rush	16.1	19.2
Ethylbenzene	FR	Sac	0.7	4.8	4.3	3.9	3.8	Rush: Sac - LA	-0.4	0.3
µg/m3		LA	2.2	5.2	4.0	5.0	4.0	Non-Rush: Sac - LA	-5.4	-4.6
	FNR	Sac	3.2	-0.3	-0.7	-0.6	-0.7	Sac: Rush - Non-Rush	5.0	5.0
		LA	2.1	5.2	3.9	5.2	4.7	LA: Rush - Non-Rush	0.0	0.1
M,P-Xylene	FR	Sac	2.7	22.0	18.4	16.7	16.1	Rush: Sac - LA	1.3	2.3
µg/m3		LA	7.4	20.8	16.0	20.3	16.5	Non-Rush: Sac - LA	-10.5	-6.6
	FNR	Sac	1.8	10.7	9.2	8.9	8.9	Sac: Rush - Non-Rush	11.3	9.2
		LA	5.7	21.2	15.8	20.9	18.8	LA: Rush - Non-Rush	-0.5	0.2
O-Xylene	FR	Sac	1.5	6.9	5.7	5.2	5.1	Rush: Sac - LA	-0.3	0.0
µg/m3		LA	2.8	7.2	5.7	7.1	5.8	Non-Rush: Sac - LA	-3.5	-2.1
	FNR	Sac	0.7	3.7	3.2	3.1	3.0	Sac: Rush - Non-Rush	3.2	2.5
		LA	2.5	7.2	5.3	7.1	6.4	LA: Rush - Non-Rush	0.0	0.4
Formaldehyde	FR	Sac	4.0	7.7	8.7	na	na	Rush: Sac - LA	-2.0	-2.7
µg/m3		LA	6.7	9.6	11.4	na	na	Non-Rush: Sac - LA	5.9	11.4
	FNR	Sac	4.0	3.7	3.5	na	na	Sac: Rush - Non-Rush	7.9	5.2
		LA	21.1	-4.1	-7.9	na	na	LA: Rush - Non-Rush	-6.2	19.2

Note: a Expected n values for Sacramento are: FR (4), FNR (2)
Expected n values for Los Angeles are: FR (4), FNR (2)
Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-4B. Influence of Freeway Congestion Level on Continuous Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units						
Measure	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
CO Avg (ppm)	FR	Sac	0.0	2.1	3.1	2.2	4.2	Rush: Sac - LA	-3.0	-2.2
		LA	0.5	5.1	5.4	5.3	5.6	Non-Rush: Sac - LA	-2.9	-0.9
	FNR	Sac	0.0	1.5	3.5	2.2	3.9	Sac: Rush - Non-Rush	0.6	-0.4
		LA	1.3	4.4	4.5	4.4	4.7	LA: Rush - Non-Rush	0.7	0.9
CO Peak (ppm)	FR	Sac	0.0	10.5	22.3	11.5	25.8	Rush: Sac - LA	-23.5	9.5
		LA	1.3	34.0	12.8	31.5	14.8	Non-Rush: Sac - LA	-13.5	-5.0
	FNR	Sac	0.0	13.0	12.5	14.0	13.0	Sac: Rush - Non-Rush	-2.5	9.8
		LA	3.0	26.5	17.5	44.5	20.0	LA: Rush - Non-Rush	7.5	-4.8
Black Carbon µg/m3	FR	Sac	na	6.7	na	7.9	na	Rush: Sac - LA	-3.7	na
		LA	na	10.4	na	17.7	na	Non-Rush: Sac - LA	-3.7	na
	FNR	Sac	na	8.3	na	4.0	na	Sac: Rush - Non-Rush	-1.6	na
		LA	na	12.1	na	16.4	na	LA: Rush - Non-Rush	-1.6	na
LAS-X particle counts/cm3	FR	Sac	na	759	na	1,942	na	Rush: Sac - LA	-2,202	na
		LA	na	2,960	na	6,724	na	Non-Rush: Sac - LA	-3,046	na
	FNR	Sac	na	991	na	1,857	na	Sac: Rush - Non-Rush	-232	na
		LA	na	4,037	na	8,528	na	LA: Rush - Non-Rush	-1,077	na

Note: a Expected n values for Sacramento are: FR (4), FNR (2)
Expected n values for Los Angeles are: FR (4), FNR (2)
Values are ug/m3, unless noted otherwise in measure column
Ambient data not available to correct black carbon or LAS-X data
LAS-X OUT data corrected for sampling line losses
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-4C. Influence of Freeway Congestion Level on PM10 Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units						
Measure	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
PM 10 mass	FR	Sac	22.7	7.5	-17.2	na	na	Rush: Sac - LA	12.2	6.2
µg/m3		LA	59.5	-4.7	-23.3	na	na	Non-Rush: Sac - LA	-12.6	-25.2
	FNR	Sac	29.4	0.2	-16.0	na	na	Sac: Rush - Non-Rush	7.3	-1.1
		LA	53.8	12.8	9.2	na	na	LA: Rush - Non-Rush	-17.4	-32.5
PM10 Cd	FR	Sac	0.10	0.00	0.00	na	na	Rush: Sac - LA	-0.02	0.00
µg/m3		LA	0.10	0.02	0.00	na	na	Non-Rush: Sac - LA	-0.03	-0.03
	FNR	Sac	0.13	-0.03	-0.03	na	na	Sac: Rush - Non-Rush	0.03	0.03
		LA	0.10	0.00	0.00	na	na	LA: Rush - Non-Rush	0.02	0.00
PM10 Cr	FR	Sac	0.40	0.00	0.00	na	na	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.40	0.00	0.00	na	na	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.40	0.00	0.00	na	na	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.40	0.00	0.00	na	na	LA: Rush - Non-Rush	0.00	0.00
PM10 Mn	FR	Sac	0.04	0.00	0.00	na	na	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.04	0.00	0.00	na	na	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.04	0.00	0.00	na	na	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.04	0.00	0.00	na	na	LA: Rush - Non-Rush	0.00	0.00
PM10 Ni	FR	Sac	0.03	0.00	0.00	na	na	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	na	na	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.03	0.00	0.00	na	na	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.03	0.00	0.00	na	na	LA: Rush - Non-Rush	0.00	0.00
PM10 Pb	FR	Sac	0.03	0.00	0.00	na	na	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	na	na	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.03	0.00	0.00	na	na	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.03	0.00	0.00	na	na	LA: Rush - Non-Rush	0.00	0.00
PM10 S	FR	Sac	0.48	-0.01	-0.19	na	na	Rush: Sac - LA	0.21	0.27
µg/m3		LA	1.56	-0.23	-0.46	na	na	Non-Rush: Sac - LA	-0.03	-0.25
	FNR	Sac	0.68	-0.07	-0.20	na	na	Sac: Rush - Non-Rush	0.06	0.01
		LA	1.69	-0.04	0.06	na	na	LA: Rush - Non-Rush	-0.19	-0.52

Note: a Expected n values for Sacramento are: FR (4), FNR (2)
Expected n values for Los Angeles are: FR (4), FNR (2)
Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-4D. Influence of Freeway Congestion Level on PM2.5 Commute-Average Concentration Data

			Concentrations (corrected for Ambient) in Measure Units						
Measure	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Comparisons:	Car 1	Car 2
PM 2.5 mass	FR	Sac	5.7	8.8	1.0	14.8	7.3	Rush: Sac - LA	-3.5	1.1
µg/m3		LA	32.1	12.3	-0.1	21.6	10.0	Non-Rush: Sac - LA	-17.3	-9.5
	FNR	Sac	10.3	4.1	2.1	12.7	5.1	Sac: Rush - Non-Rush	4.7	-1.1
		LA	33.3	21.4	11.6	35.0	13.9	LA: Rush - Non-Rush	-9.1	-11.7
PM2.5 Cd	FR	Sac	0.10	0.00	0.00	0.00	0.00	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.10	0.00	0.00	0.00	0.00	Non-Rush: Sac - LA	0.09	0.05
	FNR	Sac	0.10	0.00	0.00	0.00	0.00	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.14	-0.09	-0.04	-0.09	-0.04	LA: Rush - Non-Rush	0.09	0.04
PM2.5 Cr	FR	Sac	0.40	0.00	0.00	0.00	0.00	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.40	0.00	0.00	0.00	0.00	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.40	0.00	0.00	0.00	0.00	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.40	0.00	0.00	0.00	0.00	LA: Rush - Non-Rush	0.00	0.00
PM2.5 Mn	FR	Sac	0.04	0.00	0.00	0.00	0.00	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.00	0.00	0.00	0.00	0.00	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.04	0.00	0.00	0.00	0.00	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.04	0.00	0.00	0.00	0.00	LA: Rush - Non-Rush	0.00	0.00
PM2.5 Ni	FR	Sac	0.03	0.00	0.00	0.00	0.00	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	0.00	0.00	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.03	0.00	0.00	0.00	0.00	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.03	0.00	0.00	0.00	0.00	LA: Rush - Non-Rush	0.00	0.00
PM2.5 Pb	FR	Sac	0.03	0.00	0.00	0.00	0.00	Rush: Sac - LA	0.00	0.00
µg/m3		LA	0.03	0.00	0.00	0.00	0.00	Non-Rush: Sac - LA	0.00	0.00
	FNR	Sac	0.03	0.00	0.00	0.00	0.00	Sac: Rush - Non-Rush	0.00	0.00
		LA	0.03	0.00	0.00	0.00	0.00	LA: Rush - Non-Rush	0.00	0.00
PM2.5 S	FR	Sac	0.40	0.02	-0.11	0.06	0.01	Rush: Sac - LA	0.03	0.05
µg/m3		LA	1.34	-0.01	-0.16	0.08	-0.13	Non-Rush: Sac - LA	0.19	0.30
	FNR	Sac	0.59	0.08	-0.07	0.08	0.06	Sac: Rush - Non-Rush	-0.06	-0.04
		LA	1.71	-0.11	-0.37	0.07	0.10	LA: Rush - Non-Rush	0.10	0.21

Note: a Expected n values for Sacramento are: FR (4), FNR (2)
Expected n values for Los Angeles are: FR (4), FNR (2)
Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-4E. Influence of Freeway Congestion Level on Commute-Average Associated Measures

				Measure Units						
Measure	Type	City	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Scenario Comparisons:	Car 1	Car 2
Speed	FR	Sac	na	32.5	na	na	na	Rush: Sac - LA	-9.6	na
(mph)		LA	na	42.1	na	na	na	Non-Rush: Sac - LA	1.4	na
	FNR	Sac	na	48.6	na	na	na	Sac: Rush - Non-Rush	-16.1	na
		LA	na	47.3	na	na	na	LA: Rush - Non-Rush	-5.1	na
Spacing	FR	Sac	na	68.9	na	na	na	Rush: Sac - LA	18.5	na
Range		LA	na	50.4	na	na	na	Non-Rush: Sac - LA	44.6	na
(feet)	FNR	Sac	na	90.4	na	na	na	Sac: Rush - Non-Rush	-21.4	na
		LA	na	45.7	na	na	na	LA: Rush - Non-Rush	4.7	na
Level of	FR	Sac	na	3.9	na	na	na	Rush: Sac - LA	0.5	na
Congestion		LA	na	3.3	na	na	na	Non-Rush: Sac - LA	-1.1	na
(unitless)	FNR	Sac	na	2.5	na	na	na	Sac: Rush - Non-Rush	1.3	na
		LA	na	3.6	na	na	na	LA: Rush - Non-Rush	-0.3	na
Miles Traveled	FR	Sac	na	68.3	na	na	na	Rush: Sac - LA	-15.9	na
		LA	na	84.2	na	na	na	Non-Rush: Sac - LA	3.8	na
	FNR	Sac	na	99.1	na	na	na	Sac: Rush - Non-Rush	-30.9	na
		LA	na	95.3	na	na	na	LA: Rush - Non-Rush	-11.1	na
Heavy Duty	FR	Sac	na	50%	na	na	na	Rush: Sac - LA	-32%	na
Diesel		LA	na	82%	na	na	na	Non-Rush: Sac - LA	39%	na
Influence	FNR	Sac	na	84%	na	na	na	Sac: Rush - Non-Rush	-34%	na
% of commute		LA	na	45%	na	na	na	LA: Rush - Non-Rush	37%	na

Note: a Expected n values for Sacramento are: FR (4), FNR (2)
Expected n values for Los Angeles are: FR (4), FNR (2)
Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

4.2.5 Freeway Commute Period Influence (AM vs PM)

Tables 4-5 (A thru E) summarize the concentration data for non-special commutes for all measures focusing on the influence of the rush hour period (AM or PM) on the in-vehicle concentration levels. Mean values for ambient-corrected IN 1, IN 2, OUT 1, and OUT 2 were stratified by freeway rush (FR) and freeway non-rush (FNR) commutes and computed for Sacramento and Los Angeles. To focus on the in-vehicle concentration influences for the Caprice, differences were computed between city and scenario means as given in the last column.

An initial review of the vehicle measures and the meteorology in Table 4-5E showed that while PM wind speeds were essential the same as AM in Sacramento, they were substantially higher by 5 mph in Los Angeles. Plotting the ambient-corrected in-vehicle MTBE and benzene concentrations versus wind speed for Los Angeles (see Figure 4-3) suggested that the concentration levels of both VOC's tended to increase at the lower AM wind speeds. This might have resulted from an increased dilution of the roadway microenvironmental pollutant concentrations as the wind turbulence levels increase. Another possibility is that the traffic density is different between AM and PM. Examination of the Level of Congestion for LA, however, showed no significant difference in perceived congestion, with only a slight decrease in traffic speed and spacing.

A review of the data in Tables 4-5A and 4-5B show that MTBE, benzene, $PM_{2.5}$, and CO in-vehicle concentrations are all significantly higher in LA than Sacramento during the AM, but only slightly higher in the PM. This is attributed to the lower wind speed in LA during the AM period, combined with the generally higher concentration levels in LA, compared to Sacramento. While the AM in-vehicle concentrations were typically higher for LA, Sacramento data for MTBE, benzene, $PM_{2.5}$,and CO all showed the opposite trend, being significantly higher in the PM. This appears to be associated with the significant increase in PM Level of Congestion in Sacramento (Table 4-5E), as compared to the AM periods. While Sacramento had a significantly higher PM Level of Congestion (than AM), LA data showed little difference between AM and PM congestion. The $PM_{2.5}$ and PM_{10} sulfur Ambient levels in Tables 4-show substantially higher levels in LA, compared to Sacramento, but not on a background-corrected in-vehicle basis. This was also applicable to the formaldehyde levels.

In general, the PM commutes show substantially higher background-corrected pollutant concentrations in Sacramento, while the reverse was true in Los Angeles. The primary influencing factors appear to be the substantial increase in ambient PM wind speed in LA over AM, and the higher PM Level of Congestion in Sacramento, compared to the AM.

Table 4-5A. Influence of Time of Day on Organic Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units					
Measure	Type	Time Period	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Car 1 Comparisons	
Isobutylene	Sac	AM	2.5	7.2	5.7	5.7	5.4	AM: Sac - LA	-7.0
µg/m3		PM	1.7	8.6	9.6	8.9	7.4	PM: Sac - LA	-2.6
	LA	AM	5.6	14.2	12.6	14.1	12.5	Sac: AM - PM	-1.4
		PM	5.0	11.2	11.0	12.1	10.8	LA: AM - PM	3.0
1,3-Butadiene	Sac	AM	0.3	2.4	1.7	1.8	1.6	AM: Sac - LA	-1.1
µg/m3		PM	0.2	2.3	1.9	2.3	1.8	PM: Sac - LA	-0.5
	LA	AM	0.7	3.5	2.8	3.5	2.8	Sac: AM - PM	0.1
		PM	0.3	2.8	2.3	3.0	2.4	LA: AM - PM	0.7
Acetonitrile	Sac	AM	59.4	110.4	18.1	-57.9	-2.4	AM: Sac - LA	49.9
µg/m3		PM	15.1	65.5	237.6	-12.9	107.1	PM: Sac - LA	-101.5
	LA	AM	29.9	60.5	143.7	-25.8	75.6	Sac: AM - PM	44.9
		PM	9.4	167.0	150.6	-6.1	86.4	LA: AM - PM	-106.5
DCM	Sac	AM	2.1	-0.4	-0.9	-0.8	-0.3	AM: Sac - LA	4.2
µg/m3		PM	3.1	-1.9	-1.4	-1.7	-0.9	PM: Sac - LA	-1.2
	LA	AM	7.9	-4.6	-4.0	-3.9	-4.1	Sac: AM - PM	1.6
		PM	3.3	-0.8	-0.7	-1.0	-0.8	LA: AM - PM	-3.8
MTBE	Sac	AM	6.2	16.0	10.2	13.5	12.4	AM: Sac - LA	-14.9
µg/m3		PM	2.5	22.2	19.9	21.2	15.0	PM: Sac - LA	-0.6
	LA	AM	16.7	30.9	22.6	31.4	22.8	Sac: AM - PM	-6.2
		PM	12.6	22.8	18.6	24.6	19.5	LA: AM - PM	8.1
ETBE	Sac	AM	0.2	-0.1	0.0	0.0	0.0	AM: Sac - LA	0.0
µg/m3		PM	0.5	-0.4	-0.4	-0.4	0.0	PM: Sac - LA	-0.3
	LA	AM	0.1	-0.1	-0.1	-0.1	0.0	Sac: AM - PM	0.3
		PM	0.1	-0.1	-0.1	-0.1	-0.1	LA: AM - PM	0.0
TCFM	Sac	AM	2.5	4.7	-0.1	-0.1	0.1	AM: Sac - LA	4.6
µg/m3		PM	3.3	-0.8	-0.4	-0.8	0.6	PM: Sac - LA	-0.5
	LA	AM	1.6	0.1	0.2	0.2	0.1	Sac: AM - PM	5.5
		PM	1.8	-0.3	-0.2	-0.2	-0.2	LA: AM - PM	0.3
Benzene	Sac	AM	2.4	7.8	8.2	6.8	8.6	AM: Sac - LA	-4.4
µg/m3		PM	1.3	9.0	11.0	8.9	9.0	PM: Sac - LA	-0.3
	LA	AM	4.7	12.2	10.3	12.1	10.0	Sac: AM - PM	-1.2
		PM	3.4	9.3	9.0	9.6	9.1	LA: AM - PM	2.9
Toluene	Sac	AM	7.8	19.6	13.8	13.3	15.4	AM: Sac - LA	2.9
µg/m3		PM	4.8	26.9	21.3	19.4	18.2	PM: Sac - LA	8.7
	LA	AM	27.0	16.7	8.1	15.7	9.2	Sac: AM - PM	-7.3
		PM	13.2	18.2	14.5	18.3	15.3	LA: AM - PM	-1.5
Ethylbenzene	Sac	AM	2.4	3.3	2.0	2.3	2.0	AM: Sac - LA	-3.1
µg/m3		PM	0.8	5.5	4.2	4.3	3.9	PM: Sac - LA	0.7
	LA	AM	2.6	6.4	4.1	6.1	4.2	Sac: AM - PM	-2.2
		PM	1.9	4.8	3.6	4.6	3.8	LA: AM - PM	1.6
M,P-Xylene	Sac	AM	4.5	19.6	12.7	13.4	12.4	AM: Sac - LA	-6.7
µg/m3		PM	2.4	23.1	17.6	17.6	15.4	PM: Sac - LA	4.1
	LA	AM	8.3	26.4	17.0	25.2	17.5	Sac: AM - PM	-3.5
		PM	5.2	19.0	15.1	19.1	15.7	LA: AM - PM	7.4
O-Xylene	Sac	AM	1.9	6.4	4.2	4.5	4.2	AM: Sac - LA	-2.6
µg/m3		PM	1.4	7.3	5.5	5.6	5.2	PM: Sac - LA	0.8
	LA	AM	3.2	9.0	6.0	8.8	6.0	Sac: AM - PM	-0.9
		PM	2.2	6.6	5.4	6.6	5.5	LA: AM - PM	2.4
Formaldehyde	Sac	AM	3.4	7.8	6.3	na	na	AM: Sac - LA	2.5
µg/m3		PM	5.2	6.4	9.8	na	na	PM: Sac - LA	1.2
	LA	AM	11.1	5.3	6.0	na	na	Sac: AM - PM	1.4
		PM	13.5	5.2	1.7	na	na	LA: AM - PM	0.1

Note: a Expected n values for Sacramento are: AM (5), PM (5)
Expected n values for Los Angeles are: AM (6), PM (6)
b Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-5B. Influence of Time of Day on Continuous Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units					
Measure	Type	Time Period	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Car 1 Comparisons	
CO Avg (ppm)	Sac	AM	0.0	2.0	2.7	2.4	3.7	AM: Sac - LA	-2.6
		PM	0.0	2.1	3.6	2.3	4.4	PM: Sac - LA	-1.4
	LA	AM	0.6	4.6	4.5	5.2	5.2	Sac: AM - PM	-0.1
		PM	0.4	3.4	4.0	3.2	4.1	LA: AM - PM	1.1
CO Peak (ppm)	Sac	AM	0.6	8.6	9.4	16.5	12.0	AM: Sac - LA	-26.2
		PM	0.0	13.0	20.4	15.5	24.0	PM: Sac - LA	-4.3
	LA	AM	2.0	34.8	10.2	48.8	14.7	Sac: AM - PM	-4.4
		PM	0.8	17.3	11.5	20.5	14.3	LA: AM - PM	17.5
Black Carbon µg/m3	Sac	AM	na	5.4	na	5.8	na	AM: Sac - LA	-9.2
		PM	na	4.4	na	4.7	na	PM: Sac - LA	-10.3
	LA	AM	na	14.5	na	21.5	na	Sac: AM - PM	1.0
		PM	na	14.7	na	11.4	na	LA: AM - PM	-0.2
LASX total counts/cm3	Sac	AM	na	679	na	1,531	na	AM: Sac - LA	-2,958
		PM	na	818	na	1,614	na	PM: Sac - LA	-1,863
	LA	AM	na	3,637	na	7,370	na	Sac: AM - PM	-139
		PM	na	2,681	na	5,413	na	LA: AM - PM	956

Note: a Expected n values for Sacramento are: AM (5), PM (5)
Expected n values for Los Angeles are: AM (6), PM (6)
b Values are ug/m3, unless noted otherwise in measure column
Ambient data not available to correct black carbon or LAS-X data
LAS-X OUT data corrected for sampling line losses
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-5C. Influence of Time of Day on PM10 Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units					
Measure	Type	Time Period	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Car 1 Comparisons	
PM 10 mass	Sac	AM	25.5	2.6	-14.1	na	na	AM: Sac - LA	23.0
µg/m3		PM	20.7	0.4	-10.8	na	na	PM: Sac - LA	9.9
	LA	AM	80.9	-20.3	-22.0	na	na	Sac: AM - PM	2.3
		PM	61.3	-9.5	-21.3	na	na	LA: AM - PM	-10.8
PM10 Cd	Sac	AM	0.11	-0.01	-0.01	na	na	AM: Sac - LA	-0.02
µg/m3		PM	0.10	0.00	0.00	na	na	PM: Sac - LA	0.00
	LA	AM	0.10	0.01	0.00	na	na	Sac: AM - PM	-0.01
		PM	0.10	0.00	0.01	na	na	LA: AM - PM	0.01
PM10 Cr	Sac	AM	0.40	0.00	0.00	na	na	AM: Sac - LA	0.00
µg/m3		PM	0.40	0.00	0.00	na	na	PM: Sac - LA	0.00
	LA	AM	0.40	0.00	0.00	na	na	Sac: AM - PM	0.00
		PM	0.40	0.00	0.00	na	na	LA: AM - PM	0.00
PM10 Mn	Sac	AM	0.04	0.00	0.00	na	na	AM: Sac - LA	0.00
µg/m3		PM	0.04	0.01	0.00	na	na	PM: Sac - LA	0.01
	LA	AM	0.04	0.00	0.00	na	na	Sac: AM - PM	-0.01
		PM	0.04	0.00	0.00	na	na	LA: AM - PM	0.00
PM10 Ni	Sac	AM	0.03	0.00	0.00	na	na	AM: Sac - LA	0.00
µg/m3		PM	0.03	0.00	0.00	na	na	PM: Sac - LA	0.00
	LA	AM	0.03	0.00	0.00	na	na	Sac: AM - PM	0.00
		PM	0.03	0.00	0.00	na	na	LA: AM - PM	0.00
PM10 Pb	Sac	AM	0.03	0.01	0.00	na	na	AM: Sac - LA	0.01
µg/m3		PM	0.03	0.00	0.00	na	na	PM: Sac - LA	0.00
	LA	AM	0.03	0.00	0.00	na	na	Sac: AM - PM	0.01
		PM	0.03	0.00	0.00	na	na	LA: AM - PM	0.00
PM10 S	Sac	AM	0.64	-0.06	-0.21	na	na	AM: Sac - LA	0.49
µg/m3		PM	0.37	-0.03	-0.15	na	na	PM: Sac - LA	0.42
	LA	AM	2.18	-0.56	-0.51	na	na	Sac: AM - PM	-0.03
		PM	2.58	-0.45	-0.56	na	na	LA: AM - PM	-0.10

Note: a Expected n values for Sacramento are: AM (5), PM (5)
Expected n values for Los Angeles are: AM (6), PM (6)
b Values are ug/m3, unless noted otherwise in measure column
na Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-5D. Influence of Time of Day on PM2.5 Commute-Average Concentration Data

				Concentrations (corrected for Ambient) in Measure Units					
Measure	Type	Time Period	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Car 1 Comparisons	
PM 2.5 mass µg/m3	Sac	AM	9.6	3.6	-0.7	11.8	8.1	AM: Sac - LA	-3.9
		PM	7.4	4.4	1.8	10.8	1.8	PM: Sac - LA	-0.2
	LA	AM	49.3	7.5	-4.3	25.2	0.9	Sac: AM - PM	-0.7
		PM	36.4	4.6	-4.3	14.8	-0.7	LA: AM - PM	2.9
PM2.5 Cd µg/m3	Sac	AM	0.10	0.00	0.01	0.00	0.00	AM: Sac - LA	0.01
		PM	0.10	0.00	0.00	0.00	0.00	PM: Sac - LA	0.00
	LA	AM	0.11	-0.01	-0.01	-0.01	-0.01	Sac: AM - PM	0.00
		PM	0.10	0.00	0.01	0.00	0.00	LA: AM - PM	-0.01
PM2.5 Cr µg/m3	Sac	AM	0.40	0.00	0.00	0.00	0.00	AM: Sac - LA	0.00
		PM	0.40	0.00	0.00	0.00	0.00	PM: Sac - LA	0.00
	LA	AM	0.40	0.00	0.00	0.00	0.00	Sac: AM - PM	0.00
		PM	0.40	0.00	0.00	0.00	0.00	LA: AM - PM	0.00
PM2.5 Mn µg/m3	Sac	AM	0.04	0.00	0.00	0.00	0.00	AM: Sac - LA	0.00
		PM	0.04	0.00	0.00	0.00	0.00	PM: Sac - LA	0.00
	LA	AM	0.04	0.00	0.00	0.00	0.00	Sac: AM - PM	0.00
		PM	0.04	0.00	0.00	0.00	0.00	LA: AM - PM	0.00
PM2.5 Ni µg/m3	Sac	AM	0.03	0.00	0.00	0.00	0.00	AM: Sac - LA	0.00
		PM	0.03	0.00	0.00	0.00	0.00	PM: Sac - LA	0.00
	LA	AM	0.03	0.00	0.00	0.00	0.00	Sac: AM - PM	0.00
		PM	0.03	0.00	0.00	0.00	0.00	LA: AM - PM	0.00
PM2.5 Pb µg/m3	Sac	AM	0.03	0.00	0.00	0.00	0.00	AM: Sac - LA	-0.01
		PM	0.03	0.00	0.00	0.00	0.00	PM: Sac - LA	0.00
	LA	AM	0.03	0.01	0.00	0.01	0.00	Sac: AM - PM	0.00
		PM	0.03	0.00	0.00	0.00	0.00	LA: AM - PM	0.01
PM2.5 S µg/m3	Sac	AM	0.53	0.03	-0.15	0.07	-0.05	AM: Sac - LA	0.32
		PM	0.34	-0.02	-0.11	0.01	-0.02	PM: Sac - LA	0.43
	LA	AM	2.04	-0.30	-0.53	-0.01	-0.40	Sac: AM - PM	0.05
		PM	2.59	-0.45	-0.62	-0.07	-0.48	LA: AM - PM	0.15

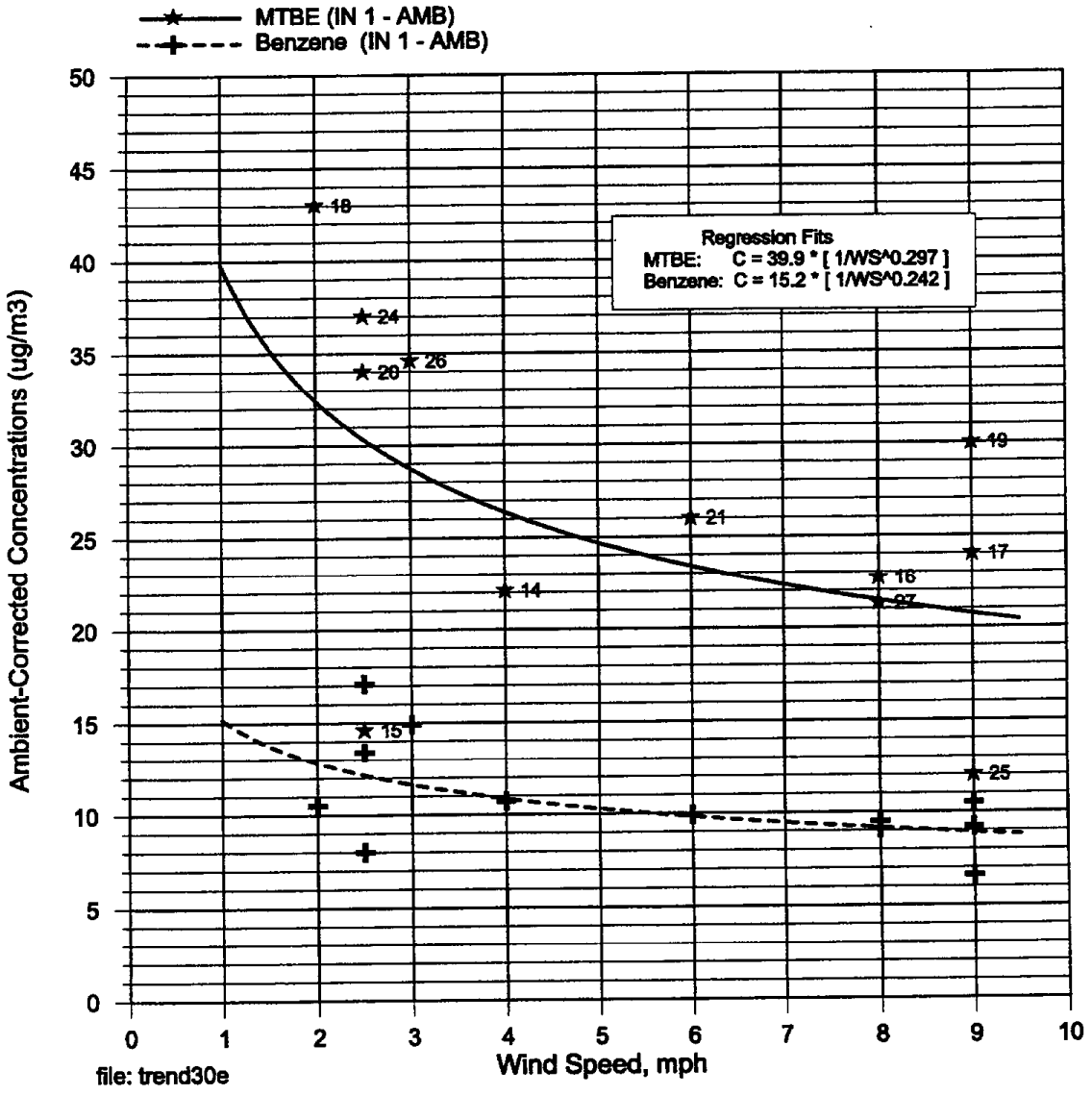
Note: a Expected n values for Sacramento are: AM (5), PM (5)
Expected n values for Los Angeles are: AM (6), PM (6)
b Values are ug/m3, unless noted otherwise in measure column
NA Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Table 4-5E. Influence of Time of Day on Commute-Average Associated Measures & Meteorology

			Measures in specified units						
Measure	Type	Time Period	AMB mean	IN 1 mean	IN 2 mean	OUT 1 mean	OUT 2 mean	Inside Car 1 Comparisons	
Measure									
Speed	Sac	AM	na	35.9	na	na	na	AM: Sac - LA	1.1
(mph)		PM	na	28.7	na	na	na	PM: Sac - LA	-6.6
	LA	AM	na	34.7	na	na	na	Sac: AM - PM	7.2
		PM	na	35.3	na	na	na	LA: AM - PM	-0.5
Spacing	Sac	AM	na	69.6	na	na	na	AM: Sac - LA	28.1
Range		PM	na	81.2	na	na	na	PM: Sac - LA	20.0
(feet)	LA	AM	na	41.5	na	na	na	Sac: AM - PM	-11.7
		PM	na	61.3	na	na	na	LA: AM - PM	-19.7
Level of	Sac	AM	na	2.2	na	na	na	AM: Sac - LA	-1.1
Congestion		PM	na	3.9	na	na	na	PM: Sac - LA	0.9
(unitless)	LA	AM	na	3.3	na	na	na	Sac: AM - PM	-1.7
		PM	na	3.0	na	na	na	LA: AM - PM	0.3
Miles Traveled	Sac	AM	na	73.7	na	na	na	AM: Sac - LA	12.2
		PM	na	59.8	na	na	na	PM: Sac - LA	-14.5
	LA	AM	na	61.6	na	na	na	Sac: AM - PM	14.0
		PM	na	74.3	na	na	na	LA: AM - PM	-12.8
Heavy Duty	Sac	AM	na	38%	na	na	na	AM: Sac - LA	-5%
Diesel		PM	na	39%	na	na	na	PM: Sac - LA	11%
Influence	LA	AM	na	43%	na	na	na	Sac: AM - PM	-1%
% of commute		PM	na	28%	na	na	na	LA: AM - PM	15%
WindSpeed	Sac	AM	4.3	na	na	na	na	AM: Sac - LA	1.5
mph		PM	4.9	na	na	na	na	PM: Sac - LA	-3.3
	LA	AM	2.8	na	na	na	na	Sac: AM - PM	-0.6
		PM	8.2	na	na	na	na	LA: AM - PM	-5.4
Temp	Sac	AM	71.2	na	na	na	na	AM: Sac - LA	-4.6
deg. F		PM	78.4	na	na	na	na	PM: Sac - LA	-0.4
	LA	AM	75.8	na	na	na	na	Sac: AM - PM	-7.2
		PM	78.8	na	na	na	na	LA: AM - PM	-3.0
Relative	Sac	AM	73.6	na	na	na	na	AM: Sac - LA	23.5
Humidity		PM	32.2	na	na	na	na	PM: Sac - LA	-15.4
%	LA	AM	50.1	na	na	na	na	Sac: AM - PM	41.4
		PM	47.6	na	na	na	na	LA: AM - PM	2.5

Note: a Expected n values for Sacramento are: AM (5), PM (5)
Expected n values for Los Angeles are: AM (6), PM (6)
b Values are ug/m3, unless noted otherwise in measure column
NA Not Available (no samples scheduled)
AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2
ROAD - both roadside sites, ROAD 1 - roadside site 1, ROAD 2 - roadside site 2

Figure 4-3. ARB Main Study Ambient-Corrected MTBE and Benzene Data versus Wind Speed for Los Angeles Commutes (only)



4. 3 Special Study Commutes

A number of commutes focused on specific scenarios defined by ARB that could broaden the information base from the program. These included a single rural commute in Sacramento to indicate the in-vehicle levels that might be encountered in a very low traffic density, background setting. Two school bus commutes were included in Sacramento which utilized a school bus as Vehicle 2, simulating a selected actual school system route with student stops. To estimate the potential concentration reductions from traveling in the typically less-traveled carpool lane, two freeway rush hour commutes were made in Los Angeles where Vehicle 1 traveled in a designated freeway carpool lane on I-10, while Vehicle 2 remained in the "slow" lanes on the same freeway. Two maximum concentration commutes in Los Angeles were included at the conclusion of the study, to estimate the in-vehicle concentration levels if the commuter carried out specific actions, including a re-fueling stop, driving in downtown street canyon, and closely trailing smoking city diesel buses.

4.3.1 Rural Commute

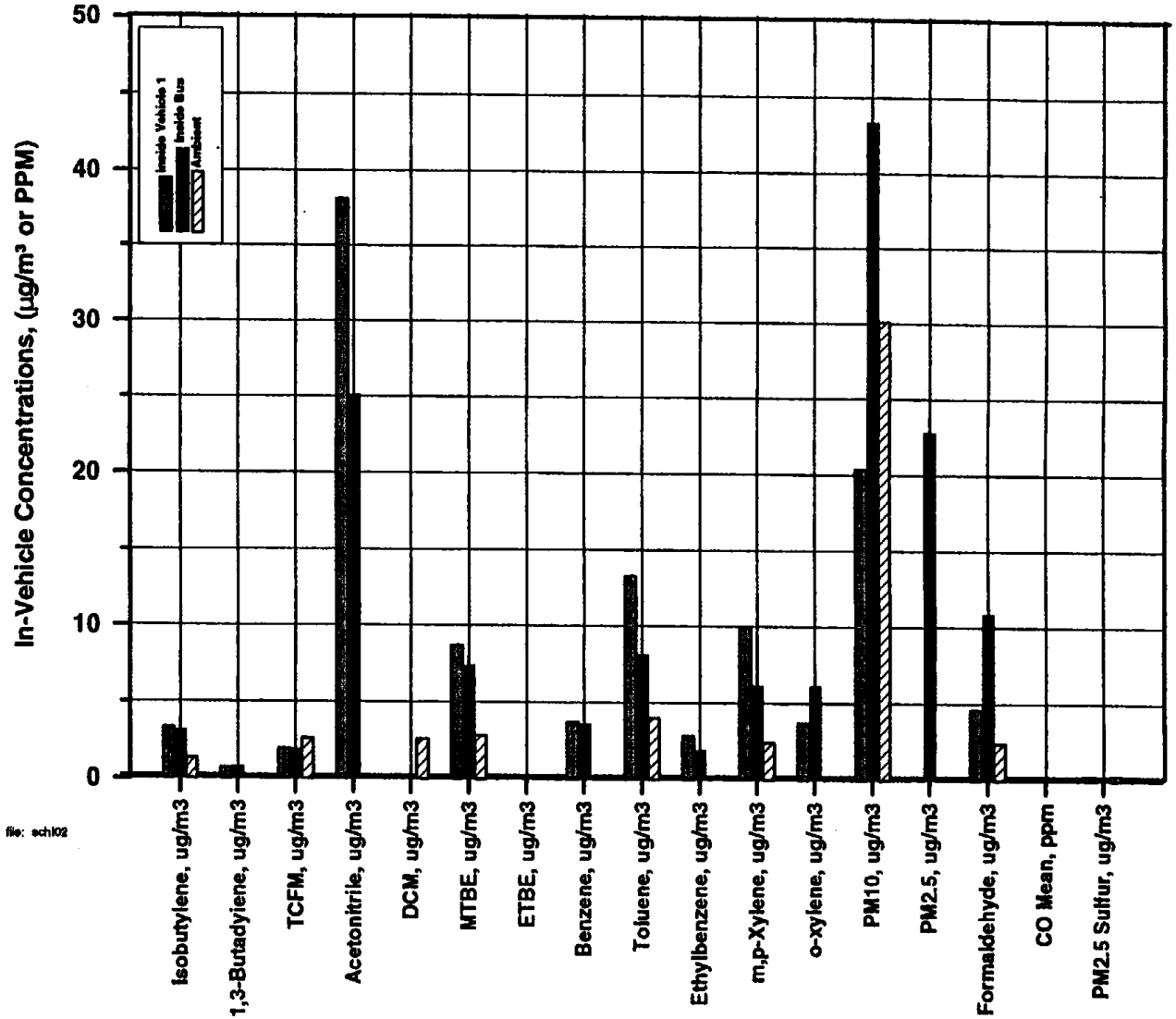
The concentrations in the Sacramento rural (R) commute approached the MQL's for almost every pollutant, as shown in Tables 3-4A thru 3-4D, and Appendix H-9. The minimal traffic volume permitted the vehicles to proceed at or above the posted speed limits for the entire 2 hour period. While no ambient station data were available for this commute, two roadside samplers were established which indicated concentrations that were even lower than the in-vehicle concentrations by 1/2 to 1/3. Rural commutes would obviously exhibit extremely low exposures for all measured pollutants.

4.3.2 School Bus Commutes

In order to estimate the levels of study pollutants inside a typical 30 foot California diesel school bus, measurements were made in the center of the bus (student seating) with three of the windows on each side 1/2 down. A typical Sacramento neighborhood school bus route (see section 2.2.2 and the detailed route description in Appendix G) was driven repeatedly from a neighborhood to the school and back, during both an AM and a PM period. In the AM commute, Vehicle 1 lead the diesel school bus, while in the PM commute, Vehicle 1 trailed the bus to estimate the levels that may be encountered behind a bus. Outside sampling incorporated a sample line to the front of the bus, while inside sampling was accomplished in the fourth row of seats on the driver's side.

The summary data for composites of the two school bus (SB) commutes by pollutant/measure are given in Tables 3-4A thru F. The individual pollutant/measure data are also provided in Appendix tables H-12 and H-13. A separate summary of the school bus data, providing the differences between Vehicle 1 and the school bus for both AM and PM commutes are given in Tables 4-6A and 4-6B. Figure 4-4 and 4-5 are graphical summaries of the AM and PM commutes, respectively, for selected pollutants for the inside measures.

Figure 4-4. Comparison of Inside School Bus Concentrations with Inside Vehicle 1 Concentrations (car leading bus) for AM Commute



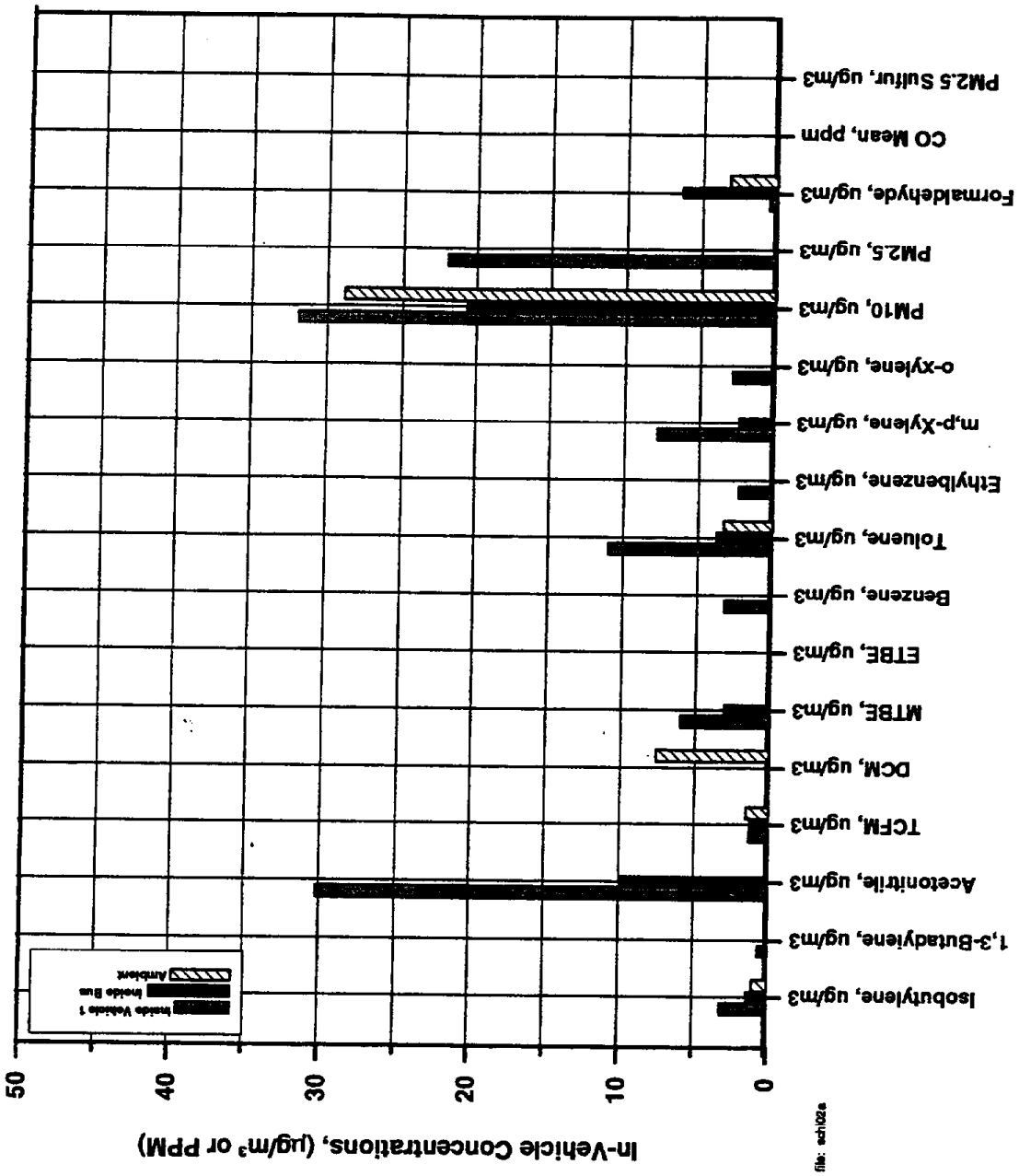


Figure 4-5. Comparison of Inside School Bus Concentrations with Inside Vehicle 1 Concentrations (car trailing bus) for PM Commute

The most obvious feature of the school bus data (e.g. see Table 3-4A) are that the pollutant measures are substantially lower in general for both ambient level and Vehicle 1 concentrations for most pollutants, compared to most of the commute types. The predominantly residential nature of the bus commutes and the associated very light traffic on the commute route resulted in MTBE levels that were significantly lower than either freeway or arterial commutes. Tables 4-6A and B show that most of the VOC's were slightly lower inside the school bus, while PM_{10} mass was somewhat higher when Vehicle 1 was leading. The $PM_{2.5}$ concentrations were too near or <MDL to compute differences. The open bus windows during both commutes apparently resulted in very similar inside and outside VOC data for the bus. The open windows appear to have resulted in higher PM_{10} concentrations inside the bus, as compared to Vehicle 1. The total LAS-X particle counts doubled (but were still quite low) when trailing the bus in the PM (as compared to AM), as did the black carbon. The black carbon data showed an increase of ~4 $\mu g/m^3$ while trailing, suggesting that soot carbon accounted for a significant portion of the increased particle mass.

Table 4-6A. Summary of Pollutants for AM School Bus Commute (Vehicle 1 Leading)							
				IN			OUT
		IN 1	IN 2	Bus - Caprice	OUT 1	OUT 2	Bus - Caprice
	Ambient	Caprice	School Bus	difference	Caprice	School Bus	difference
Isobutylene, µg/m3	1.3	3.3	3.1	-0.2	2.7	1.9	-0.8
1,3-Butadyiene, µg/m3	BDL	0.7	0.8	0.1	BDL	0.9	-0.9
Acetonitrile, µg/m3	68.7	38.1	25.1	-13.0	3.0	BDL	nc
TCFM, µg/m3	2.6	1.9	1.9	0.0	2.0	-40.0	-42.0
DCM, µg/m3	2.6	BDL	BDL	nc	BDL	0.3	-0.3
MTBE, µg/m3	2.8	8.7	7.4	-1.3	7.6	4.2	-3.4
ETBE, µg/m3	BDL	BDL	BDL	nc	BDL	BDL	nc
Benzene, µg/m3	BDL	3.7	3.6	-0.1	3.2	3.4	0.2
Toluene, µg/m3	4.0	13.3	8.1	-5.2	9.6	4.4	-5.2
Ethylbenzene, µg/m3	BDL	2.8	1.9	-0.9	2.1	1.8	-0.3
m,p-Xylene, µg/m3	2.4	9.9	6.1	-3.8	7.0	3.5	-3.5
o-xylene, µg/m3	BDL	3.7	6.1	2.4	2.6	2.3	-0.3
PM10, µg/m3	30.1	20.4	43.4	23.0	na	na	nc
PM2.5, µg/m3	BDL	BDL	22.8	nc	BDL	BDL	nc
Formaldehyde, µg/m3	2.4	4.6	10.9	6.3	0.0	9.9	9.9
CO Mean, ppm	BDL	BDL	BDL	nc	BDL	0.4	nc
PM2.5 Sulfur, µg/m3	0.28	0.24	0.21	-0.03	0.09	-0.02	-0.11
Black Carbon, µg/m3	na	0.9	na	nc	4.8	na	nc
LAS-X particles/cm3	na	18.0	na	nc	63.0	na	nc
NOTES:	Values are ug/m3, unless noted otherwise in measure column						
	na Not Available (no samples scheduled)						
	AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside						
	BDL - below detection limit			nc - not computed			

Table 4-6B. Summary of Pollutants for PM School Bus Commute (Vehicle 1 Trailing)							
				IN			OUT
		IN 1	IN 2	Bus - Caprice	OUT 1	OUT 2	Bus - Caprice
	Ambient	Caprice	School Bus	difference	Caprice	School Bus	difference
Isobutylene, µg/m3	1.0	3.1	1.4	-1.7	2.9	1.1	-1.8
1,3-Butadyiene, µg/m3	BDL	0.6	BDL	nc	0.6	BDL	nc
Acetonitrile, µg/m3	64.7	30.2	10.0	-20.2	2.2	28.8	26.6
TCFM, µg/m3	1.5	1.3	1.3	0.0	1.5	1.0	-0.5
DCM, µg/m3	7.6	BDL	BDL	nc	BDL	BDL	nc
MTBE, µg/m3	BDL	6.0	3.1	-2.9	4.8	2.3	-2.5
ETBE, µg/m3	BDL	BDL	BDL	nc	BDL	BDL	nc
Benzene, µg/m3	BDL	3.2	BDL	nc	2.4	BDL	nc
Toluene, µg/m3	3.3	11.0	3.8	-7.2	6.5	3.7	-2.8
Ethylbenzene, µg/m3	BDL	2.3	BDL	nc	BDL	BDL	nc
m,p-Xylene, µg/m3	BDL	7.8	2.4	-5.4	4.5	BDL	nc
o-xylene, µg/m3	BDL	2.8	BDL	nc	BDL	BDL	nc
PM10, µg/m3	28.9	31.9	20.7	-11.2	na	na	nc
PM2.5, µg/m3	BDL	22.0	BDL	nc	BDL	BDL	nc
Formaldehyde, µg/m3	3.2	0.5	6.4	5.9	na	na	nc
CO Mean, ppm	BDL	BDL	NS	nc	BDL	BDL	nc
PM2.5 Sulfur, µg/m3	0.19	0.24	0.22	-0.02	0.21	0.22	0.01
Black Carbon, µg/m3	na	8.9	na	nc	9.2	na	nc
LAS-X particles/cm3	na	29	na	nc	129	na	nc
NOTES:	Values are ug/m3, unless noted otherwise in measure column						
	na Not Available (no samples scheduled)						
	AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside						
	BDL - below detection limit			nc - not computed			

4.3.3 Carpool Lane Commutes

Two freeway commutes (one AM rush and one PM rush) were conducted in which Vehicle 1 commuted in the carpool lane of I-10 and Vehicle 2 (Ford Explorer) remained the slower non-carpool lanes. The commute route is shown on the map in Appendix C. The differences in congestion between the carpool lane and the non-carpool lanes resulted in a substantial increase in the miles driven in the carpool lane (97.1 miles (@ 48.5 mph) in the carpool lane vs 67.7 miles (@ 33.9 mph) in the non-carpool lanes during 2 hour commutes).

The freeway rush carpool (FRC) commute data are summarized in Tables 3-5A thru F, and in Table 4-7, indicating the differences between vehicles. The individual carpool commute data are found in Appendix tables H-22 and H-23. Figure 4-6 is a graphical summary of selected pollutants for the outside carpool measurements, while Figure 4-7 plots the inside carpool measures. The inside vehicle data show that the concentrations are significantly lower in the carpool lane for all pollutants. The number at the top of each set of bars indicates the percent reduction in concentration from driving in the carpool lane, with a negative sign indicating that the carpool lane value is higher than the non-carpool. In general, the VOC's are 30 to 50 % higher inside the non-carpool lane vehicle (Figure 4-7). Formaldehyde and CO are 21 % and 36 % higher, respectively. While PM_{10} is 16 % higher in Vehicle 2, $PM_{2.5}$ is 8 % lower. This seemed inconsistent at first, but review of the outside vehicle data in Figure 4-6 shows that the $PM_{2.5}$ levels are actually 92 % higher in the non-carpool lane. The differences in inside particle concentrations are apparently influenced by particle losses in the vehicle ventilation systems, and partially by the generally lower vehicle AER rate values (see Figure 3-6), accentuated by the lower vehicle speeds in the non-carpool lanes.

In order to estimate the differences in commuting exposures, a hypothetical 30 mile commute was utilized, and the total commute times required for carpool and non-carpool commutes computed (37.1 minutes for carpool, and 53.1 minutes for non-carpool). The pollutant concentration differences were then weighted by their respective commute times to provide the estimated exposure levels in $\mu g/m^3$ - minutes (or ppm - minutes). In order to remove the differences between vehicle AER's, the outside vehicle concentrations were used. The resulting exposures are shown in Figure 4-8, with the percent differences computed. In general, the pollutant exposures are 90 to 180 % higher in the non-carpool lane.

Table 4-7. Summary Composites of Pollutants for Two Carpool Lane Commutes							
				IN			OUT
		IN 1	IN 2	Explorer - Caprice	OUT 1	OUT 2	Explorer - Caprice
	Ambient	Caprice	Explorer	difference	Caprice	Explorer	difference
Isobutylene, µg/m3	3.8	14.2	19.4	5.2	14.2	20.1	5.9
1,3-Butadyiene, µg/m3	0.4	3.0	4.0	1.0	2.9	3.9	1.0
TCFM, µg/m3	1.5	1.5	1.5	0.0	1.5	1.6	0.1
Acetonitrile, µg/m3	76.9	46.2	69.1	22.9	2.1	48.4	46.3
DCM, µg/m3	2.4	2.6	3.3	0.7	2.5	4.0	1.5
MTBE, µg/m3	10.2	31.2	47.0	15.8	31.2	47.8	16.6
ETBE, µg/m3	0.2	0.0	0.0	0.0	0.0	0.0	nc
Benzene, µg/m3	3.0	12.7	17.4	4.7	12.3	17.4	5.1
Toluene, µg/m3	10.3	31.5	50.8	19.3	29.8	46.3	16.5
Ethylbenzene, µg/m3	1.7	6.1	8.0	1.9	5.6	7.6	2.0
m,p-Xylene, µg/m3	5.2	23.6	31.0	7.4	21.9	29.3	7.4
o-xylene, µg/m3	2.0	8.5	11.1	2.6	7.9	10.5	2.6
PM10, µg/m3	102.6	61.1	71.0	9.9	na	na	nc
PM2.5, µg/m3	58.1	46.9	43.3	-3.6	41.2	78.9	37.7
Formaldehyde, µg/m3	8.9	14.0	17.0	3.0	na	na	nc
CO Mean, ppm	BMD	3.6	4.9	1.3	2.8	5.6	2.8
PM2.5 Sulfur, µg/m3	4.1	3.1	2.8	-0.3	2.3	3.2	0.9
Black Carbon, µg/m3	na	4.4	na	nc	13.3	na	nc
LAS-X particles/cm3	na	2817	na	nc	5289	na	nc
Notes:	IN 1 and OUT 1 are Vehicle 1 (Caprice) in carpool lane						
	IN 2 and OUT 2 are Vehicle 2 (Ford Explorer) in non-carpool lanes						
	Values are **not** background-corrected and are in ug/m3, unless noted otherwise in measure column						
	na Not Available (no samples scheduled)						
	AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2						
	BDL - below detection limit			nc - not computed			

Figure 4-6. Comparison of Outside-Vehicle 1 (OUT 1) Carpool Lane Concentrations With Adjacent Outside (OUT 2) Non-Carpool Lane Concentrations

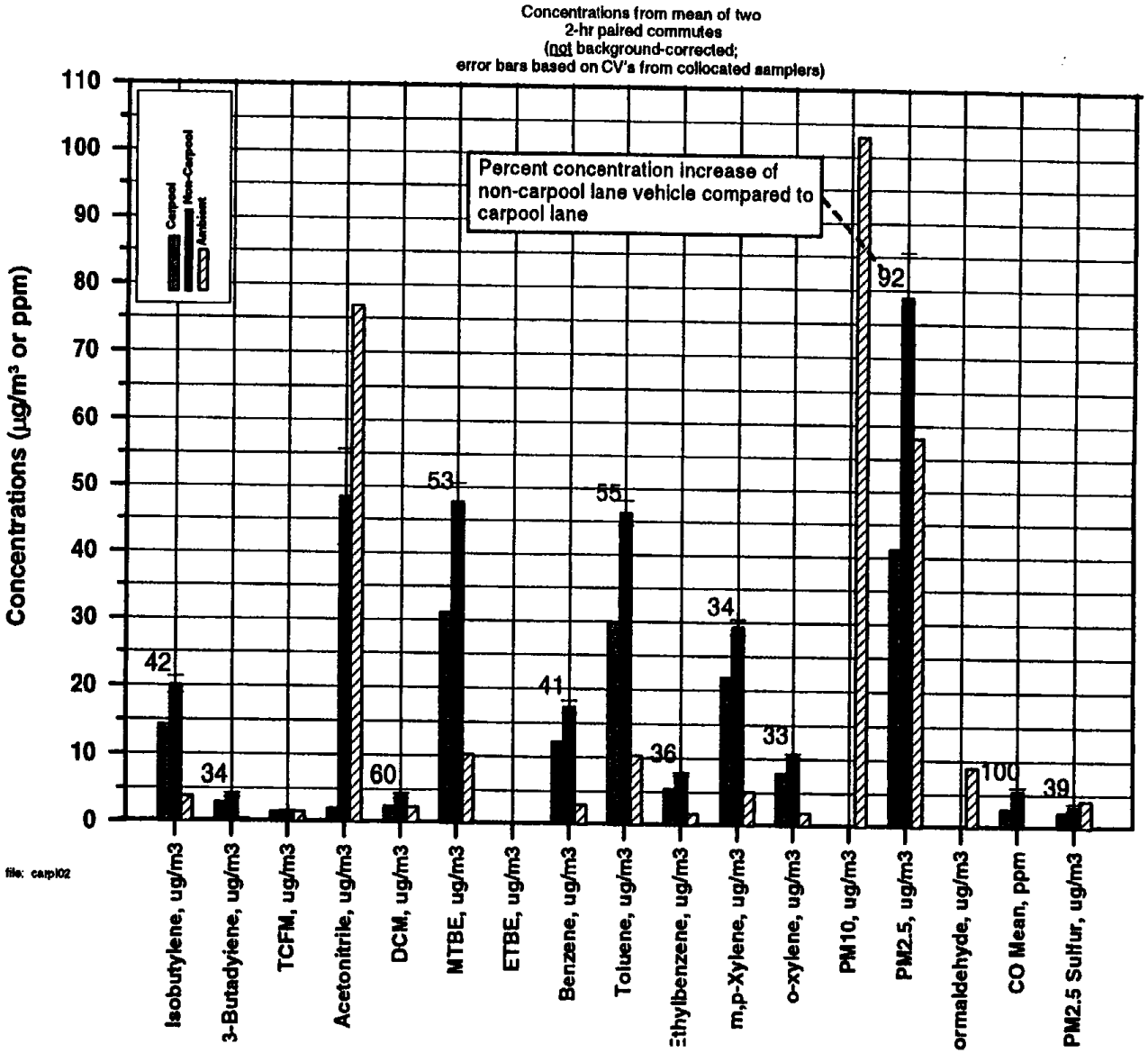


Figure 4-7. Comparison of Inside-Vehicle (IN 1) Carpool Lane Concentrations With Adjacent Lane Non-Carpool (IN 2) Concentrations

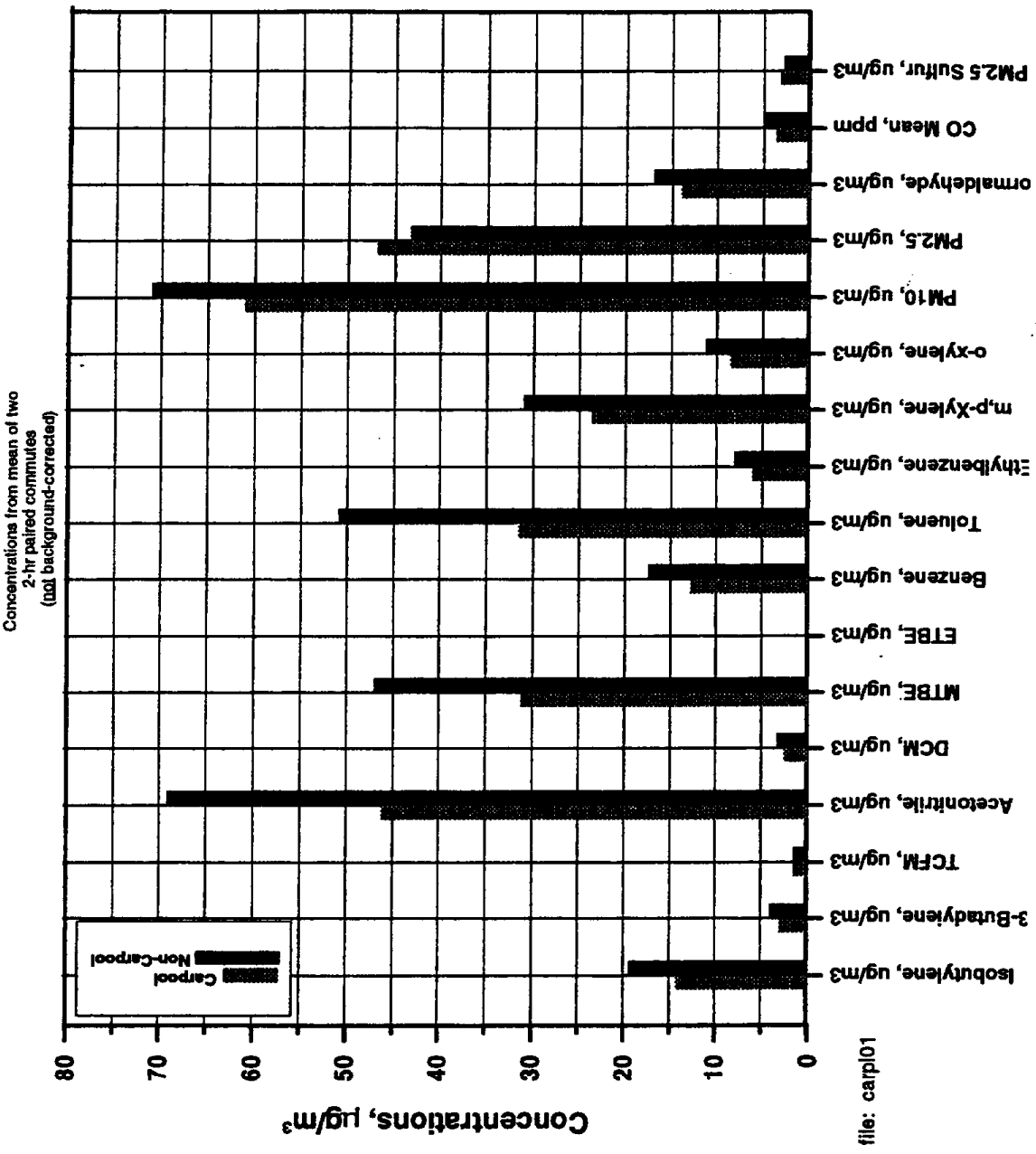
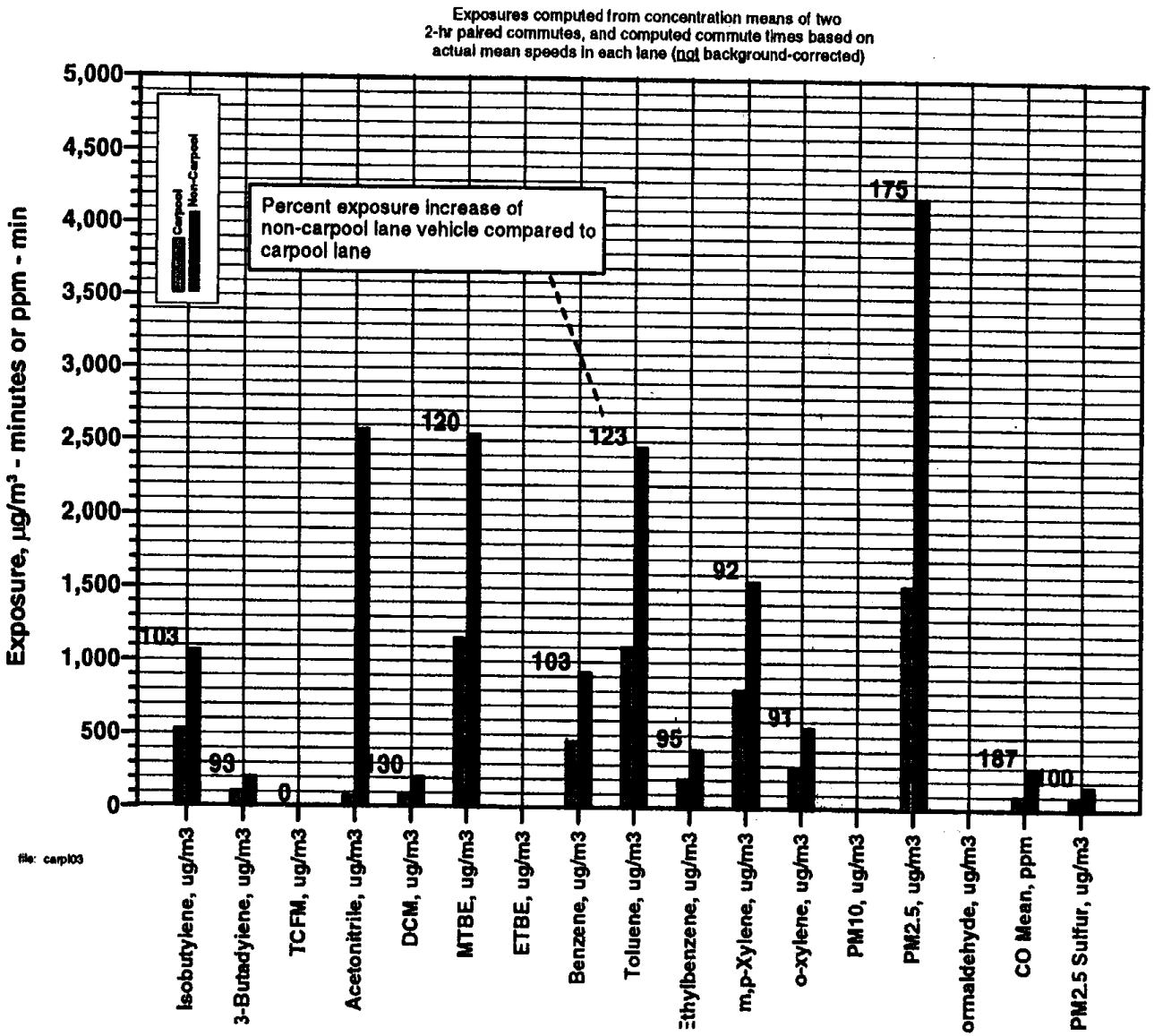


Figure 4-8. Comparison of Outside-Vehicle (OUT 1) Carpool Lane Exposures With Adjacent Outside (OUT 2) Non-Carpool Lane Exposures for an Assumed 30 Mile Commute



4.3.4 Maximum Concentration Commutes

Two commutes (one AM and one PM) were conducted in which the primary objective was placing Vehicle 1 in situations that (intuitively) could produce the maximum concentrations inside the vehicle for all pollutants, especially MTBE and particles. The detailed descriptions of the two commute routes and the drive scenarios are provided in Appendix G. The driving protocol included a gasoline refueling stop to maximize the potential of adding VOC vapor to the measured concentrations. Since smoking gasoline vehicles and diesel buses had been observed to provide the highest particle count data, these vehicles types were favored as "target" vehicles during the maximum commutes. Street canyon and depressed (or walled) roadway section situations had also been noted to provide elevated concentrations and situations with these features were also highlighted.

The maximum commute (MC) data are summarized in Tables 3-5A thru F, and in Table 4-8. The individual maximum commute data are found in Appendix tables H-28 and H-29. While the mean MTBE level was highest for MC commutes, as compared to the other scenarios in Table 3-5A1, a number of the individual commutes were higher than the lowest maximum concentration commute level. This was also true for benzene and toluene. The mean $PM_{2.5}$ and PM_{10} concentrations, particle counts, and black carbon in Table 3-5B were significantly higher for the MC commutes than any of the other scenarios, due at least partially to the higher percentage of diesel bus targets. CO was not significantly higher during the MC commutes. The total particle count data, which should reflect the higher percentage of diesel bus targets during the MC commutes, were elevated substantially for commute #29, but not quite as much for #28. The black carbon in-vehicle levels were consistently high at ~21 $\mu g/m^3$, although arterial non-rush commute #18 actually had the highest concentration at 22.9 $\mu g/m^3$. In general the maximum concentration commutes did produce significantly higher concentration levels, but not necessarily for all pollutants. The video analysis of selected commutes (see section 4.4.1) included maximum commute #29, illustrating the substantial contributions of single vehicles to elevated black carbon and particle count levels.

Table 4-8. Summary Composites of Pollutants for Two "Maximum" Commutes							
	Ambient	IN 1 Caprice	IN 2 Explorer	IN 2 - IN 1 difference	OUT 1 Caprice	OUT 2 Explorer	OUT 2 - OUT 1 difference
Isobutylene, µg/m3	4.3	21.5	na	nc	19.6	na	nc
1,3-Butadyiene, µg/m3	0.4	4.7	na	nc	4.4	na	nc
TCFM, µg/m3	1.8	2.2	na	nc	2.0	na	nc
Acetonitrile, µg/m3	52.8	28.0	na	nc	2.4	na	nc
DCM, µg/m3	5.5	4.5	na	nc	4.0	na	nc
MTBE, µg/m3	10.7	60.2	na	nc	50.9	na	nc
ETBE, µg/m3	0.0	0.0	na	nc	0.0	na	nc
Benzene, µg/m3	2.9	17.2	na	nc	15.6	na	nc
Toluene, µg/m3	10.2	37.6	na	nc	36.8	na	nc
Ethylbenzene, µg/m3	1.6	8.0	na	nc	7.5	na	nc
m,p-Xylene, µg/m3	5.2	32.5	na	nc	29.7	na	nc
o-xylene, µg/m3	2.1	11.5	na	nc	10.6	na	nc
PM10, µg/m3	56.9	89.1	na	nc	na	na	nc
PM2.5, µg/m3	21.3	83.0	na	nc	88.9	na	nc
Formaldehyde, µg/m3	10.1	61.7	na	nc	67.6	na	nc
CO Mean, ppm	BDL	4.4	na	nc	4.3	na	nc
PM2.5 Sulfur, µg/m3	2.1	2.1	na	nc	2.3	na	nc
Black Carbon, µg/m3	na	20.9	na	nc	19.9	na	nc
LAS-X particles/cm3	na	4325	na	nc	7333	na	nc
Notes:	IN 1 and OUT 1 are for Vehicle 1 (Caprice); no trailing Vehicle 2 was used for these commutes						
	Values are ug/m3, unless noted otherwise in measure column						
	na Not Available (no samples scheduled)						
	AMB - ambient site, IN 1 - inside car 1, IN 2 - inside car 2, OUT 1 - outside car 1, OUT 2 - outside car 2						
	BDL - below detection limit nc - not computed						

4.4 Selected Data Analyses

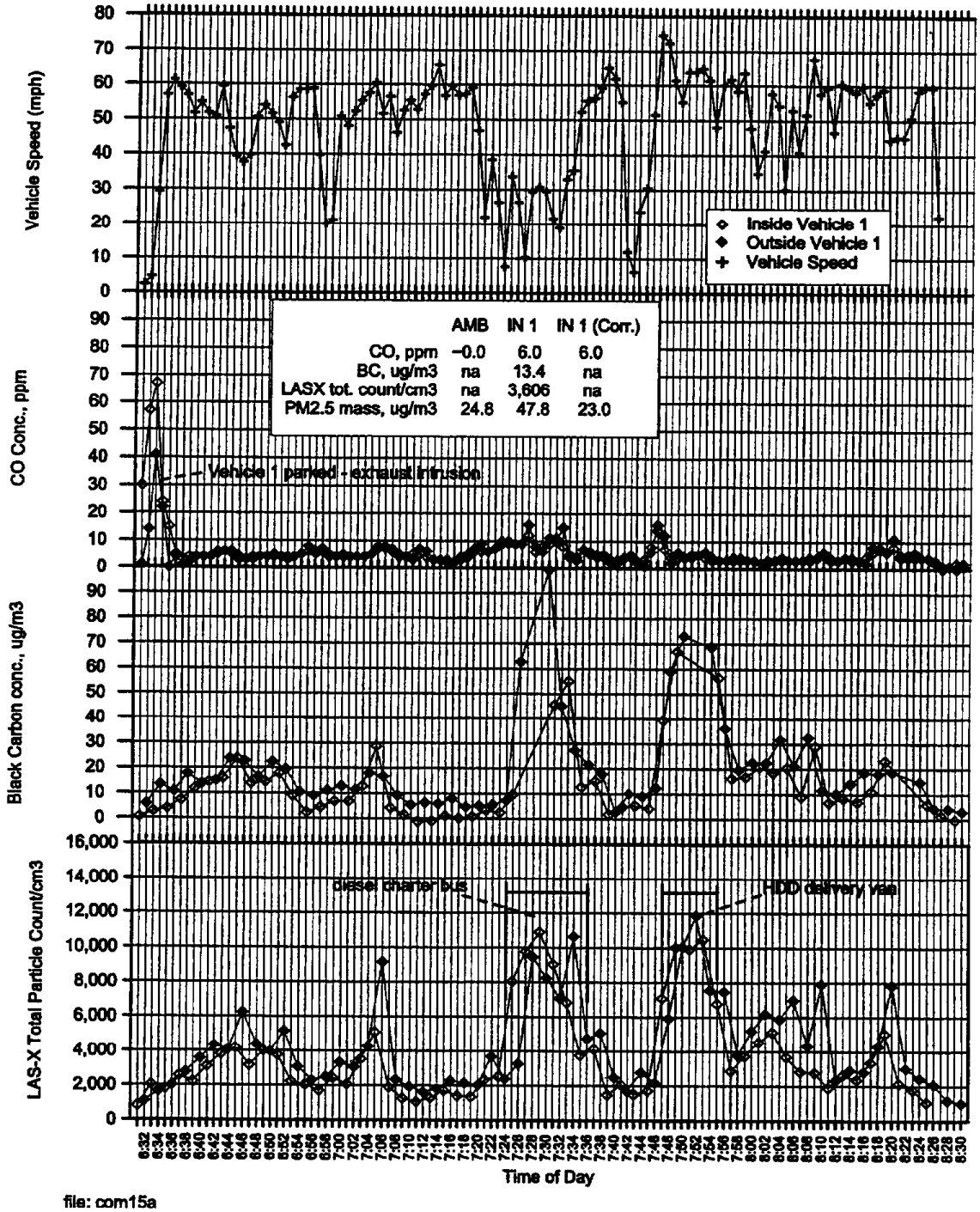
4.4.1 Video Analysis of Elevated Particle Commutes in Los Angeles

Near-real time pollutant measurements were made for CO, black carbon, and particle count in Vehicle 1. The data for these three pollutants were summarized as one minute averages for Vehicle 1. Thus 60 outside measurements were collected alternately, with 60 inside measurements during a 2 hour commute. In order to provide an indication of the situations ahead of the car that are influencing these concentrations, a video camera was operated to capture the view through the front windshield for the entire 120 minutes. By manually comparing the individual features in a graphical concentration profile with the activities occurring in front of the car, a semi-quantitative ink can be made between the presence or absence of potential commute features. These features might include "target" vehicle type, influence of the "target" exhaust location relative to the outside sampling inlet, and the influence of pollutant "trapping" features (e.g. sound walls, street canyons, etc.). A limited analysis of the video information paired with the pollutant data could provide information on the relative contributions of "target" vehicles, as well as possible mitigation steps a driver could take to reduce exposure.

In order to limit the scope of this type of analysis, a limited scheme was proposed in which the five highest concentration commutes (based primarily on integrated $PM_{2.5}$) in Los Angeles were selected. The commute selection was assisted by ranking the outside $PM_{2.5}$ particle concentrations in Appendix K. From this ranking the commutes chosen were to include the highest concentrations in each scenario category - FR, FNR, AR, ANR, and MC. The respective commute numbers for these scenarios were: 15, 14, 26, 17, and 29.

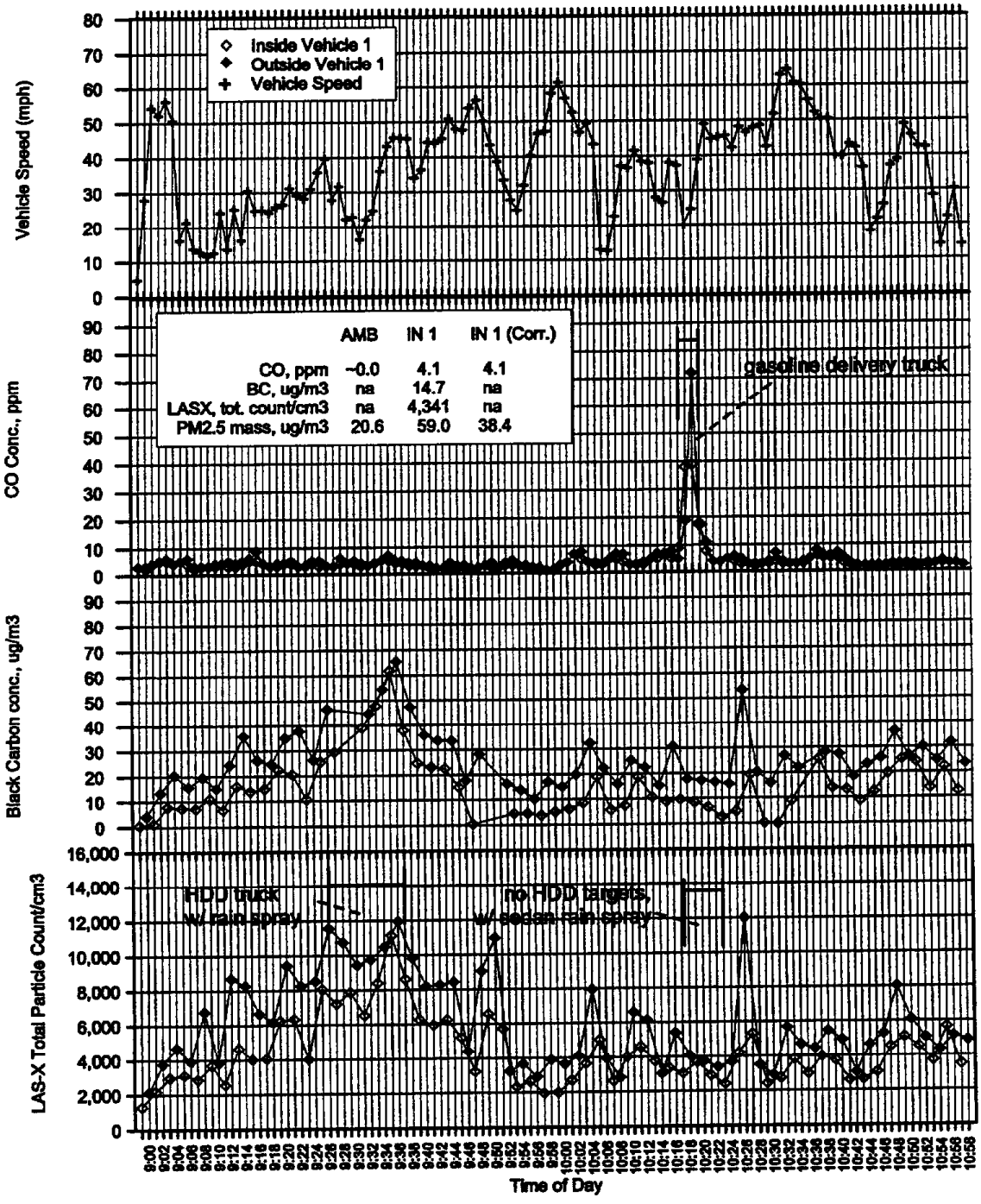
The continuous inside vehicle data for CO, black carbon, and particle count for the identified commutes were then consolidated along with the vehicle speed to provide the graphs shown in Figures 4-9 thru 4-13. Note that the concentration scales by pollutant are not necessarily the same on all graphs. The video records for each commute were then reviewed to identify the "target" vehicle and/or situation that appeared to lead to the significant peak concentrations from the graphs. The logs from these video observations are provided in Tables 4-9 thru 4-13. Note also that even though the relational observations are only "inferences" (since an exact cause-and-effect link between the peak levels and the "target" vehicles can only be inferred), the consistent relationship between certain targets (especially diesel buses) and roadway situations (primarily "cut sections" or street canyons) provides credibility. While it is not possible to completely describe the images on a 2 hour video in this report, an attempt has been made to identify the salient observations. The identification of key features (especially vehicle types) observed were assisted by the audio descriptions provided by the experienced Sierra navigator and driver.

Figure 4-9. ARB Main Study Los Angeles Continuous Data
Vehicle Speed, CO, BC, and Count
Commute #15, 9/26/97 AM, FR



file: com15a

Figure 4-10. ARB Main Study Los Angeles Continuous Data
Vehicle Speedg, CO, BC, and Count
Commute #14, 9/25/97 AM, FNR [Raining]



file: com14a

Figure 4-11. ARB Main Study Los Angeles Continuous Data
Vehicle Speed, CO, BC, and Count
Commute #26, 10/2/97 AM, AR

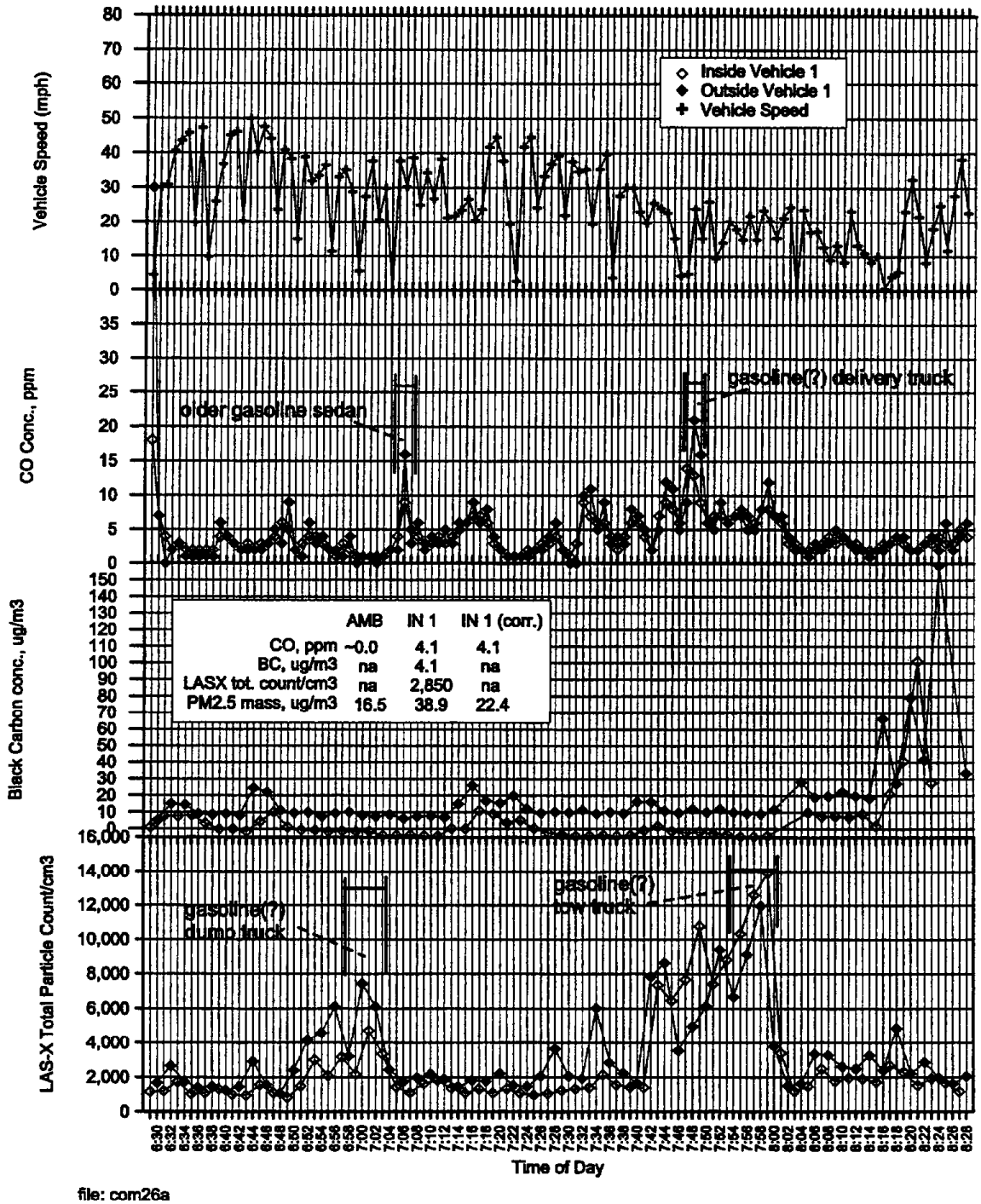
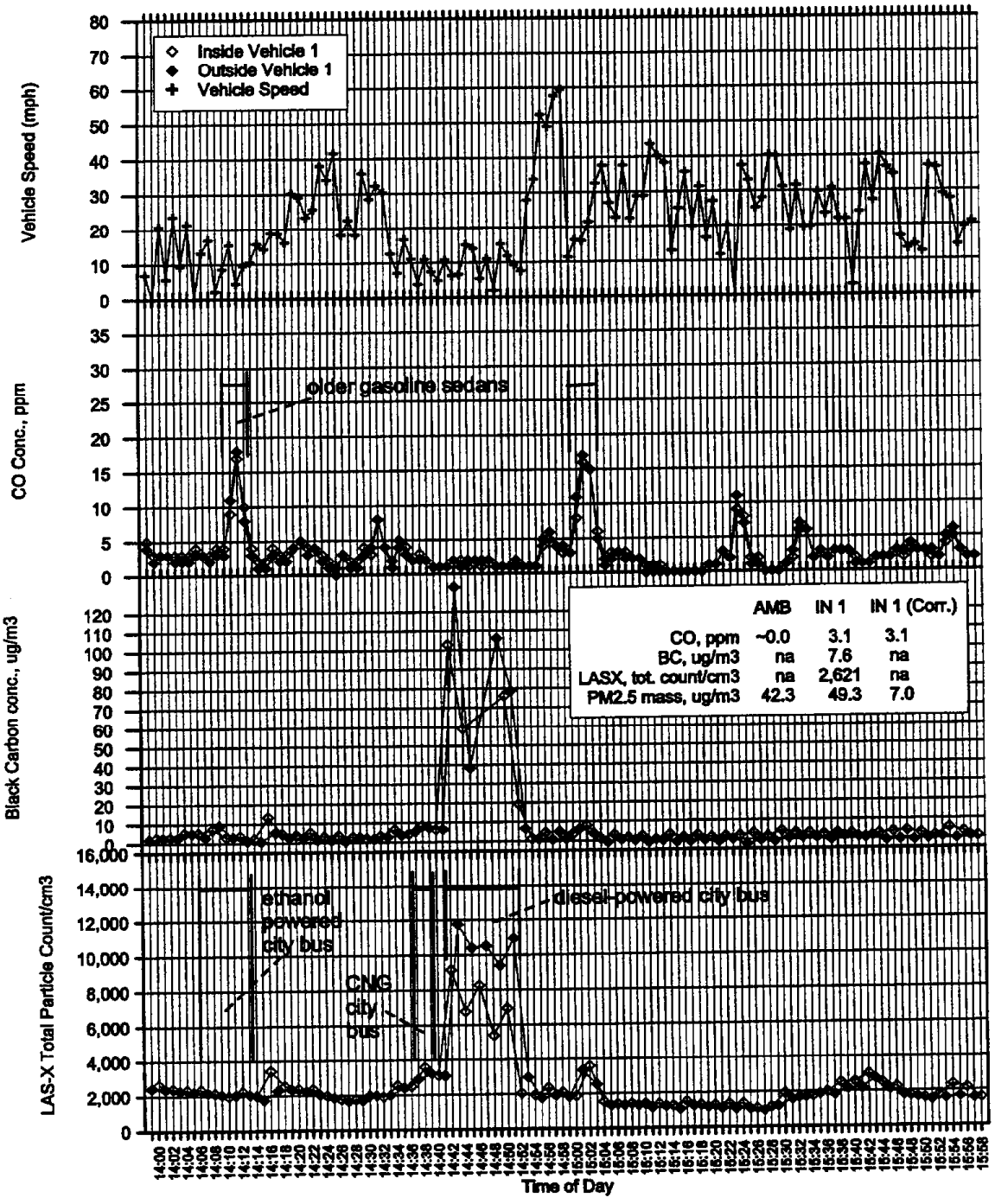
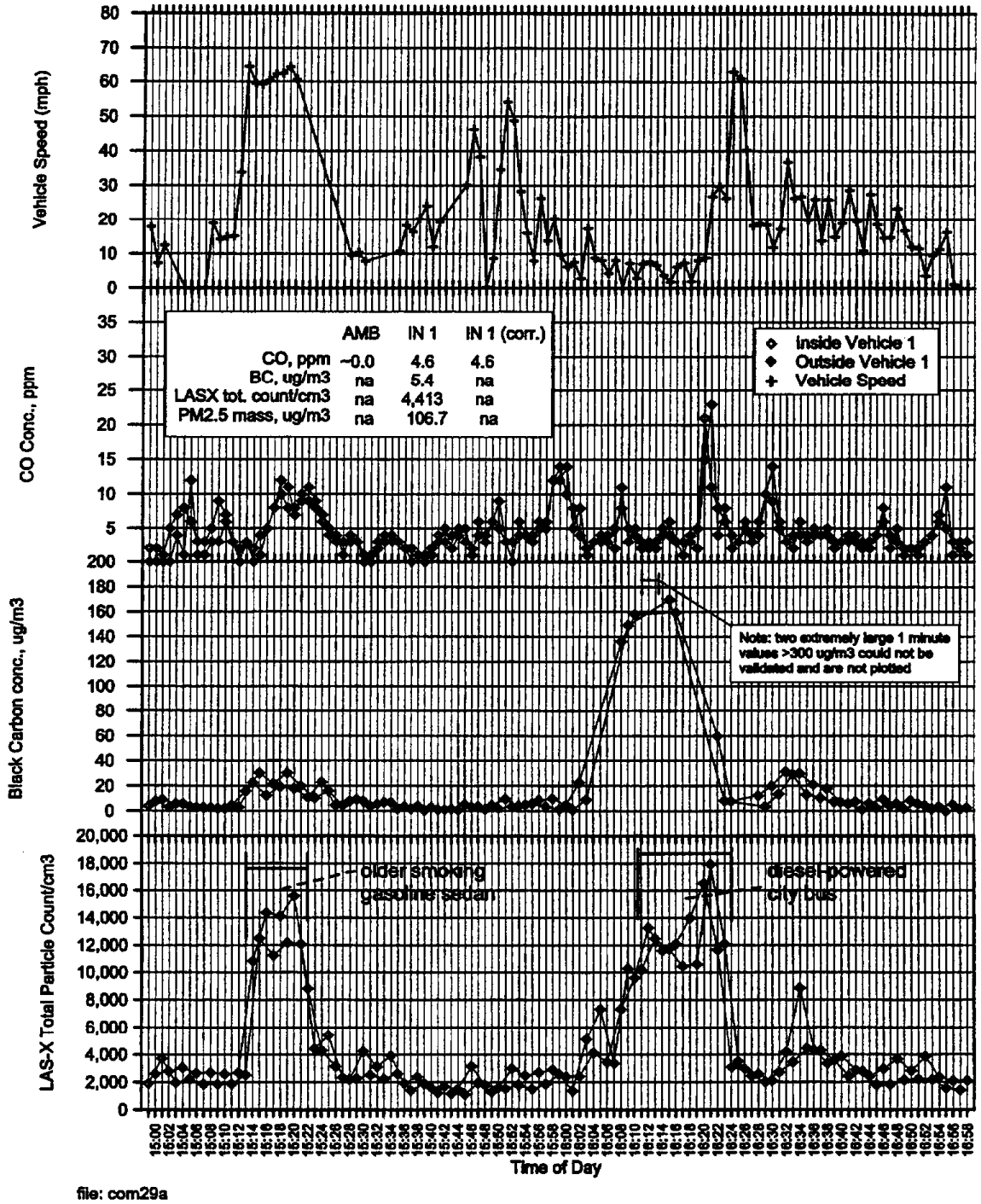


Figure 4-12. ARB Main Study Los Angeles Continuous Data
Vehicle Speed, CO, BC, and Count
Commute #17, 9/27/97 PM, ANR



file: com17a

Figure 4-13. ARB Main Study Los Angeles Continuous Data
Vehicle Speed, CO, BC, and Count
Commute #29, 10/3/97 PM, MC



file: com29a

Table 4-9. ARB In-Vehicle Main Study LA Commute Video Observations			
	Commute:	**#15, 9/26/97 AM, FR**	
Entry #	Time of Day	Observation	Observed Signif. Target Type (if any)
1	6:38:00	in traffic	
2	6:43:00	behind truck	HDD
3	6:52:00	loose truck	
4	6:52:30	behind truck	HDD
5	6:55:00	loose truck	
6	7:04:00	behind truck	HDD
7	7:06:00	school bus ahead of truck	bus type diesel?
8	7:07:00	loose truck and bus	
9	7:15:00	delivery truck	gasoline?
10	7:25:30	smoking charter bus	diesel bus
11	7:39:00	loose bus	
12	7:44:00	behind older sedan	gasoline
13	7:48:00	behind delivery van	diesel?
14	7:55:00	loose van	
15	7:57:00	behind gravel truck	HDD
16	7:59:00	behind semi	HDD
17	8:06:00	behind gasoline truck	HDD
18	8:10:00	behind delivery van	HDD
19	8:20:00	behind smoking tractor (no trailer)	HDD

Table 4-10. ARB In-Vehicle Main Study LA Commute Video Observations			
	Commute:	**#14, 9/25/97 AM, FNR (raining)**	
Entry #	Time of Day	Observation	Observed Signif. Target Type (if any)
1	9:02:00	on-ramp	
2	9:07:00	small truck	diesel?
3	9:08:00	off-ramp	
4	9:09:20	behind several trucks	HDD's
5	9:12:00	stop and go traffic; behind truck	HDD
6	9:18:00	behind truck	HDD
7	9:26:00	behind several trucks	HDD's
8	9:28:00	heavy spray from truck	HDD
9	9:32:00	stop and go; heavy spray	HDD
10	9:45:00	stop and go; loose truck	
11	9:49:00	behind truck	HDD
12	9:52:00	off ramp (video clock quit)	
13	10:06:00	behind cement truck; stop and go	HDD?
14	10:15:50	loose cement truck	
15	10:20:40	behind delivery truck	gasoline?
16	10:24:00	loose truck	
17	10:28:00	behind tanker	HDD
18	10:29:00	loose truck	
19	10:34:00	behind truck; stop and go	HDD

Table 4-11. ARB In-Vehicle Main Study LA Commute Video Observations			
	Commute:	#26, 10/2/97 AM, AR	
Entry #	Time of Day	Observation	Observed Signif. Target Type (if any)
1	6:38:00	stoplight behind older sedan	
2	6:42:00	stoplight	
3	6:48:00	stoplight behind older pickup truck	
4	6:52:00	behind cement truck	HDD
5	6:56:00	loose cement truck	
6	6:58:00	behind dump truck	diesel?
7	7:00:00	close behind dump truck at stoplight	diesel?
8	7:04:00	loose dump truck	
9	7:06:00	stoplight behind older sedan	
10	7:21:00	behind tanker truck	HDD
11	7:23:00	loose tanker truck	
12	7:33:30	behind older pickup truck	
13	7:34:00	behind delivery truck	diesel?
14	7:36:00	loose truck	
15	7:38:00	behind older van	
16	7:39:00	loose van	
17	7:44:00	behind delivery truck	diesel?
18	7:48:00	video clock stopped	
19	7:49:00	on-ramp	
20	7:49:30	behind tow truck	diesel?
21	7:54:00	cut section of highway	
22	7:59:00	behind delivery truck	HDD
23	8:01:00	loose truck	
24	8:05:00	behind city bus	diesel
25	8:10:00	loose bus	
26	8:12:00	behind city bus in street canyon	diesel
27	8:17:00	loose bus	
28	8:20:00	behind city bus	diesel

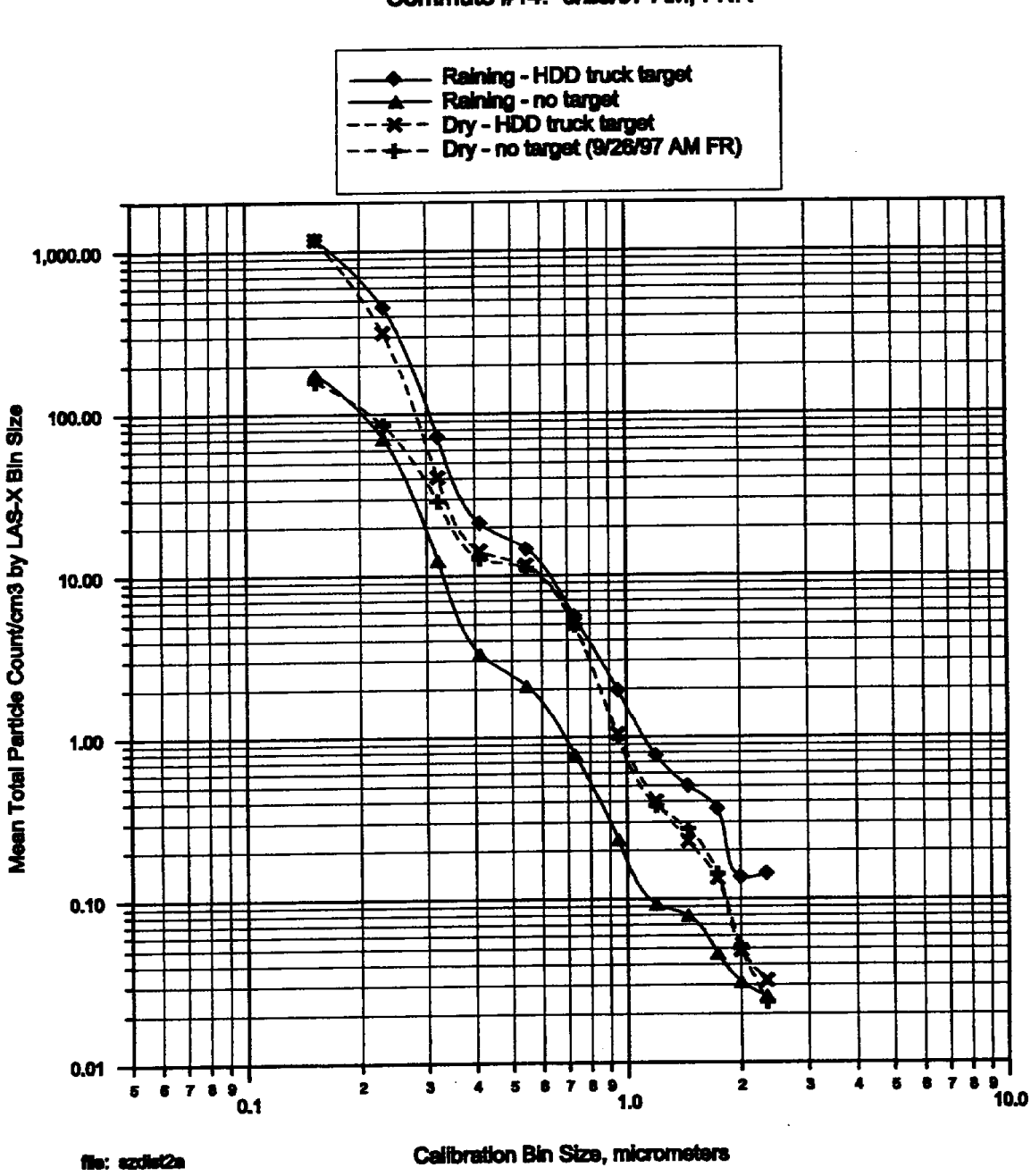
Table 4-12. ARB In-Vehicle Main Study LA Commute Video Observations			
	Commute:	#17, 9/27/97 PM, ANR	
Entry #	Time of Day	Observation	Observed Signif. Target Type (if any)
1	02:06:25	behind stopped city bus	ethanol powered
2	2:11:40	loose bus	
3	2:13:00	long stoplight	older sedan
4	2:15:00	very light traffic	
5	2:35:00	downtown	
6	2:39:00	behind stopped city bus	CNG powered
7	2:43:00	behind city bus; stop and go	diesel
8	2:53:00	loose bus	
9	2:56:00	street canyon	
10	3:02:00	behind older sedan	
11	3:24:00	long traffic light - gasoline odor	

Table 4-13. ARB In-Vehicle Main Study LA Commute Video Observations			
	Commute:	#29, 10/3/97 PM, MC	
Entry #	Time of Day	Observation	Observed Signif. Target Type (if any)
1	3:02:00	stoplight	
2	3:04:00	fast-food drive-thru	older sedan
3	3:08:40	target leaves	
4	3:09:00	no traffic	
5	3:10:00	stoplight	
6	3:13:30	on-ramp	
7	3:14:00	sound wall	
8	3:14:30	behind truck	HDD
9	3:15:00	visibly smoking car	older sedan
10	3:23:00	behind wrecker	diesel?
11	3:23:30	off ramp	
12	3:25:00	stoplight	older sedan; diesel schoolbus
13	3:31:00	downtown	
14	3:33:30	street canyon	
15	3:40:00	delivery truck	HDD?
16	3:41:00	heavy traffic	
17	3:43:00	light traffic	
18	3:45:30	on-ramp	
19	3:47:00	cut section	
20	3:50:00	off-ramp	
21	3:51:00	stopped traffic	
22	3:52:00	on-ramp	
23	3:56:00	2nd behind truck	HDD
24	3:59:00	off-ramp	
25	4:01:30	behind parked bus	diesel bus
26	4:04:00	behind bus (#2089)	diesel bus
27	4:04:30	stoplight	diesel bus
28	4:06:00	stop and go	diesel bus
29	4:06:30	loose bus	
30	4:08:00	stop and go	diesel bus
31	4:10:00	behind bus	diesel bus
32	4:19:00	street canyon	diesel bus
33	4:23:30	loose bus	
34	4:26:00	on-ramp	
35	4:29:40	cement truck	diesel?
36	4:32:00	loose truck	
37	4:34:00	stop and go; adjacent truck	HDD
38	4:36:00	cement truck	diesel?
39	4:43:20	behind truck - looks new	HDD
40	4:50:00	adjacent ot truck	HDD
41	4:52:30	off-ramp	stoplight

The more salient graphical features (peaks) were paired with the video logs and marked on the graphs. Figures 4-9 and 4-10 show the inside vehicle real-time data for the highest FR and FNR commutes, respectively. The particle count and black carbon data in Figure 4-9 are dominated by two events trailing a diesel charter bus and a diesel delivery van. CO shows little, if any, elevation during these diesel events. The elevated CO levels at the start of the commute resulted from Vehicle 1's own exhaust intrusion while still in the parking lot. The over-laid summary table indicates that the freeway contribution to the integrated $PM_{2.5}$ mass concentration is 23 $\mu g/m^3$. Figure 4-10 shows a dramatically different commute picture for particles and BC, apparently due to the heavy rain that fell during this commute (the only rainfall noted during the 29 Main Study commutes). While conventional wisdom suggests that rainfall tends to remove the larger particle sizes from the air and minimize resuspension from pavement dust, the $PM_{2.5}$ contribution was just over 38 $\mu g/m^3$, the 2nd highest level of the Main Study. A review of the video showed that while HDD trucks were being followed during this commute, the standing water on the pavement was producing substantial spray from the wheels during the first half of the commute. The rain (and associated spray level) decreased somewhat from approximately 10 to 11 AM. Both the particle count and black carbon data were dramatically elevated during this commute, especially until 10 AM, even though the frequency of HDD targets was roughly the same during the entire period. Plotting selected intervals of the particle count distributions[7] from the FR and FNR commutes in Figure 4-14, shows that a substantially difference in particle count is apparent with and without an HDD truck present. Over-laying HDD truck presence and absence events from the following (9/26/97) dry freeway day, shows that above approximately 0.3 μm, there is little difference in size distribution, suggesting as expected that diesels contribute primarily to the <0.3 μm size range. Above this size, the presence of rain apparently provides a substantial increase in particle count - which apparently translates into significant particle mass. Below ~0.7 μm, the distributions for HDD diesel-influenced events is virtually identical. At the lowest detectable size (0.15 μm) the presence and absence of HDD vehicle graphs merge. A possible explanation is the potential for the particles present on the roadway, prior to the rain (it hadn't rained in LA for a number of days prior to this commute), to be mixed with the water spray and released by droplet drying. The elevation of particle sizes less than 1 μm in size, however, was unexpected. Examination of the particle elemental data for $PM_{2.5}$ and PM_{10} in Tables F-27 thru F-30 for these two commutes, shows substantial increases in both the $PM_{2.5}$ and PM_{10} concentrations for Si, Ca, K, Ti, Fe, and Zn for the rainy commute #14 compared to the drier commute #15. While these elements are normally associated only with larger particle sizes, resuspended pavement dust may have been a significant contributor to the in-vehicle concentrations when following heavy duty vehicles on the rainier day. This phenomenon merits further investigation.

[7] More classical particle size distribution formats are shown in Appendix F, normalizing the particle count by bin size, and providing cumulative % less than relationships. Simple particle count/cm3 by bin size is presented for clarity and provides essentially the same conclusions relating the size distributions.

Figure 4-14. Selected Particle Count Size Distributions from LAS-X Particle Data - Rain vs No Rain



The CO levels during commute #14 were very low, except for a short period following an apparently out of tune, gasoline-fueled delivery truck. The collection of an ambient size distribution with which to background-correct the in-vehicle distributions should be considered in future studies to better delineate microenvironmental contributions by particle size.

Figures 4-11 and 4-12 show the continuous data for the highest AR and ANR commutes. Figure 4-11 shows two relatively large particle count peaks, which were both produced by vehicles (a delivery truck and a tow truck) that appear to have been gasoline, instead of diesel powered. Note that the elevated particle counts are not associated with elevated black carbon peaks, characteristic of diesel emissions. Figure 4-15 shows the particle size distributions associated with these two gasoline vehicles. The higher particle counts for the tow truck are probably associated with the pollutant trapping nature of the roadway "cut" section.

Figure 4-12 shows a single large peak for both particle count and black carbon, resulting from following a diesel city bus. Interestingly, during commute #17, an ethanol-powered city bus and a CNG-powered city bus were also followed. Plotting the representative particle size distributions from these three source types (see Figure 4-16) shows that below ~0.3 μm the diesel bus produces substantially higher particle counts (note log scale) than either the CNG or ethanol-powered buses. Above this size, all three vehicles produce approximately the same size distribution. The two highest CO peaks (ignoring the initial self-contamination peak) in Figure 4-11 were associated with an older sedan and a delivery truck, both of which were gasoline fueled. Similarly, the two highest CO peaks in Figure 4-12 were associated with following older gasoline-fueled sedans.

The continuous data for the highest concentration (MC, #29) commute during the Los Angeles portion of the study is represented in Figure 4-13, and again shows that trailing a few individually polluting vehicles can substantially increase the commute-average particle concentrations. The first of the two large particle count peaks were associated with a smoking gasoline-powered sedan. The second peak was from an apparently poorly-tuned (visibly smoking) diesel bus in a downtown street canyon area. Note that while the typical particle count levels ranged from ~100,000 to 200,000/min when not following these two vehicles, they increased to over 700,000/min (11,700 particles/cm^3) for the total ~20 minutes trailing times. Computing a simple time weighted average suggests that 48 percent of the total particle exposure for the 2 hour commute was contributed by 2 poorly tuned vehicles. The size distributions of these two events (see Figure 4-17) were very similar.

4.4.2 $PM_{2.5}$ Fraction of PM_{10}

The size of the $PM_{2.5}$ (Fine particle fraction) relative to PM_{10} (Fine + Coarse fraction) provides an indication of the distribution of particles in the atmosphere (using the AMB) data, and the relative contributions of fine and coarse particles from the commuting microenvironment. This type of analysis is easily confounded, however, since intervening sources (especially for coarse particles) between the ambient site and the microenvironment readily alter the ratio. The experimental errors associated with integrated particle measurements near or below the MQL can also substantially bias computing ratios.

Figure 4-15. Selected Particle Count Size Distributions from LAS-X Particle Data - Probable Gasoline Trucks

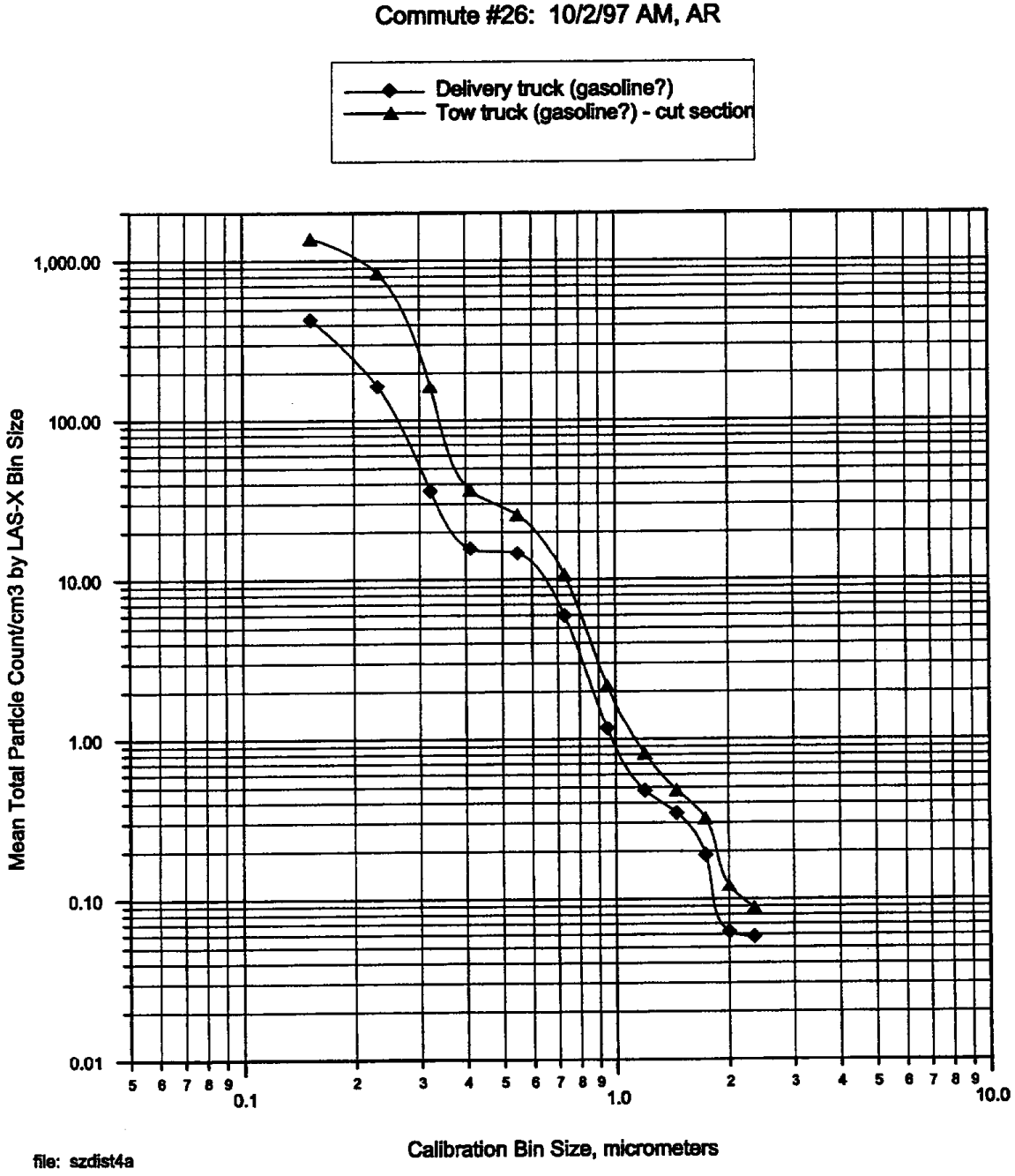


Figure 4-16. Selected Particle Count Size Distributions from LAS-X Particle Data - Bus Fuel Comparison

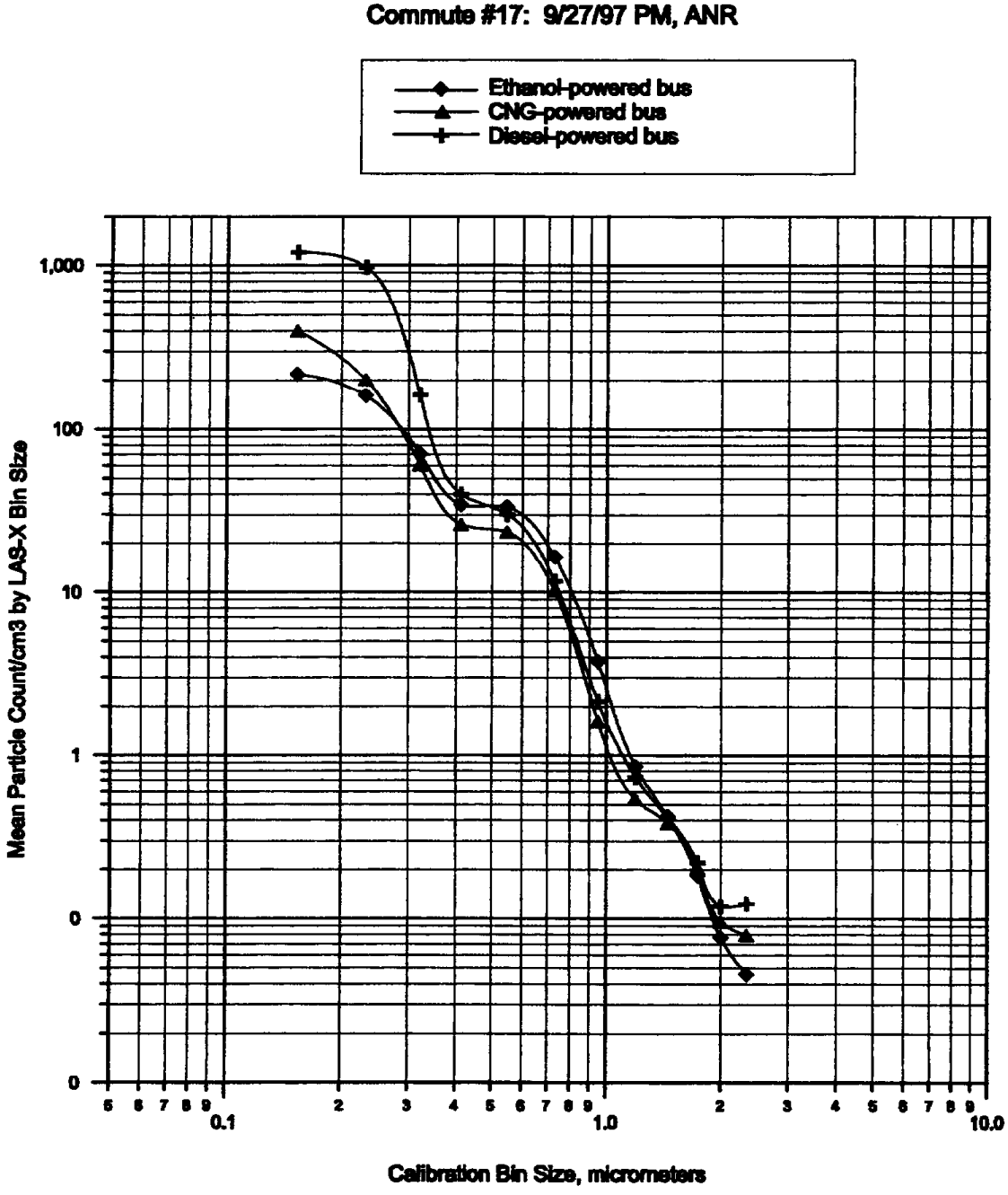
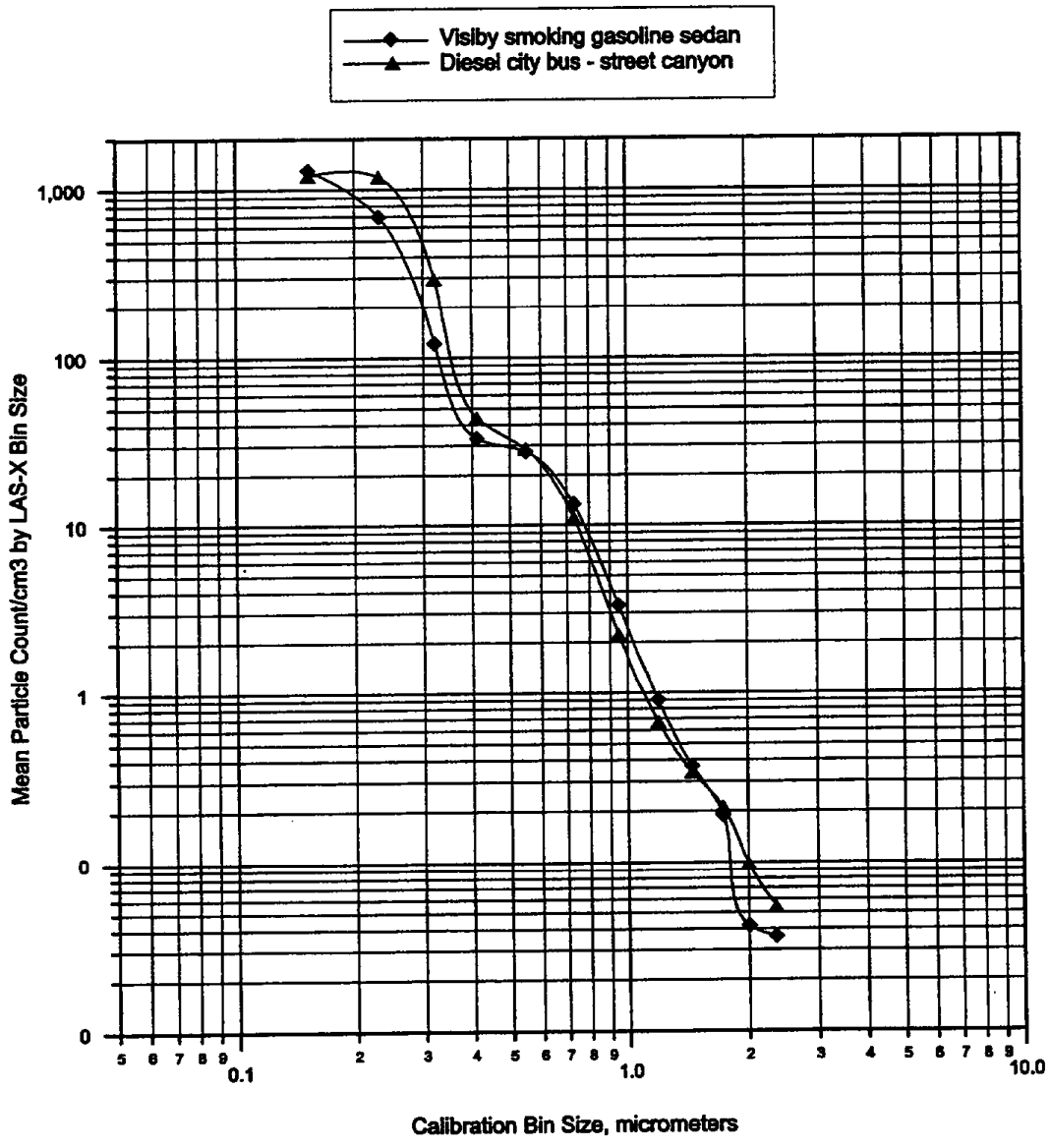


Figure 4-17. Selected Particle Count Size Distributions from LAS-X Particle Data - Gasoline Sedan/Diesel Bus



file: szdist05

Table 4-14 provides a summary of the computed $PM_{2.5}$ to PM_{10} ratios for both Sacramento and Los Angeles for data above the MDL. The much lower Sacramento concentrations, relative to the MDL, provided much less consistent trends, than did the more robust measurements in LA. In general, $PM_{2.5}$ was ~58% of the PM_{10} in LA with a +/- 15% coefficient of variation, while Sacramento was 38%, and more variable at +/- 31 %. As the measurement locations got closer to the vehicles, the Fine fractions tended to become larger proportions of the PM_{10} . The ratios at the LA roadside sites averaged 61%, with similar roadside ratios for Sacramento averaging ~42%. The in-vehicle ratios were ~84% in LA, and ranged between 57 and 84% in Sacramento. The in-vehicle ratios, are partially affected by particle losses, as a function of size, in the vehicle ventilation systems. While vehicle wheels and turbulence generate Coarse particles during re-entrainment of pavement and roadside dusts (dry periods), vehicular exhausts generate Fine particles (typically less than 0.3 μm) from combustion. While $PM_{2.5}$ /PM_{10} ratios can exceed 1.0 as a result of experimental error, the ratio could be expected to approach 1.0 as vehicular exhaust predominated. The limited number of ratios exceeding the expected measurement precisions, supports the excellent quality assessment of the integrated particle data.

Normalizing the ratios to the ambient site ratio for the day, provided a mean of estimating the fractional change resulting from the vehicular microenvironment. Note that the IN 1 normalized ratios averaged approximately 50% higher than the ambient sites for both Sacramento and LA. The ratios at the roadside sites averaged only 10 to 30% higher than those at the ambient site. In general the ratio changes relative to background were reasonably consistent between Sacramento and LA.

Table 4-14. PM2.5 to PM10 Ratios by Commute and Location

	Ratios computed for data above MDL only						PM2.5 / PM10 Ratios					Ratios nomalized to AMB			
Day	Date	Loc.	DOW	Period	Type	Vent	IN 1	IN 2	ROAD 1	ROAD 2	AMB	IN 1	IN 2	ROAD 1	ROAD 2
1	9/9	SAC	Tu	AM	FNRH	Hi	0.399	0.776	0.429	0.345	0.496	0.805	1.565	0.865	0.696
1	9/9	SAC	Tu	PM	FNRH	Hi	0.579	1.254							
2	9/10	SAC	We	AM	FRH	Hi	0.367								
2	9/10	SAC	We	PM	FRH	Hi	0.717								
3	9/11	SAC	Th	AM	FRH	Lo	0.605	1.027	0.429	0.353	0.266	2.272	3.861	1.611	1.327
3	9/11	SAC	Th	PM	FRH	Lo			0.523		0.362			1.446	
4	9/12	SAC	Fr	AM	AR	Hi	0.568			0.433	0.329	1.729			1.318
4	9/12	SAC	Fr	PM	AR	Hi	0.639	1.025							
5	9/13	SAC	Sa	midday	R	Hi									
6	9/14	SAC	Mo	AM	AR	Lo	0.483	0.486			0.541	0.894	0.898		
6	9/14	SAC	Mo	PM	AR	Lo	0.676								
7	9/15	SAC	Tu	AM	SB	Hi	0.590	0.525			0.270	2.185	1.944		
7	9/15	SAC	Tu	PM	SB	Hi	0.688	0.814							
				mean SAC ratios:			**0.574**	**0.844**	**0.460**	**0.377**	**0.377**	1.577	2.067	1.307	1.114
						std. dev.	0.114	0.280	0.055	0.049	0.116	0.696	1.272	0.392	0.362
						CV %:	19.9	33.2	11.8	13.0	30.7	44.2	61.5	30.0	32.5
1	9/25	LA	Th	AM	FNRH	Hi	0.967	0.730			0.559	1.730	1.307		
2	9/26	LA	Fr	AM	FRH	Hi	0.738	0.861	0.769	0.522	0.503	1.467	1.713	1.530	1.039
2	9/26	LA	Fr	PM	FRH	Hi	0.826	0.636	0.614	0.857	0.401	2.060	1.587	1.530	2.137
3	9/27	LA	Sa	PM	ANR	Hi	0.918	1.108			0.714	1.285	1.551		
4	9/28	LA	Su	AM	ANR	Hi	1.006	0.900			0.608	1.655	1.481		
4	9/28	LA	Su	PM	FNRH	Hi	0.701	0.699			0.651	1.077	1.074		
5	9/29	LA	Mo	AM	FRH	Low	0.994	1.181	0.571	0.586	0.618	1.610	1.912	0.925	0.948
5	9/29	LA	Mo	PM	FRH	Low	0.688	0.992	0.448	0.450	0.594	1.160	1.670	0.754	0.758
6	9/30	LA	Tu	AM	FRC	Hi	0.800	0.579	0.490	0.630	0.492	1.626	1.177	0.997	1.280
6	9/30	LA	Tu	PM	FRC	Hi	0.746	0.637	0.538	0.619	0.652	1.144	0.977	0.825	0.949
7	10/1	LA	We	AM	AR	Low	1.000	0.406	0.716	0.616	0.666	1.501	0.610	1.075	0.924
7	10/1	LA	We	PM	AR	Low	0.842	0.794	0.715	0.752	0.533	1.581	1.490	1.342	1.412
8	10/2	LA	Th	AM	AR	Hi	0.907	1.231	0.637		0.533	1.701	2.308	1.194	
8	10/2	LA	Th	PM	AR	Hi	0.824	0.784	0.607	0.517	0.648	1.270	1.209	0.937	0.798
9	10/3	LA	Fr	AM	MC	Hi	0.811				0.503	1.612			
9	10/3	LA	Fr	PM	MC	Hi	1.016								
				mean LA ratios:			**0.861**	**0.824**	**0.611**	**0.617**	**0.578**	1.499	1.433	1.111	1.138
						std. dev.	0.113	0.239	0.103	0.124	0.084	0.267	0.422	0.279	0.430
						CV %:	13.1	29.0	16.9	20.2	14.6	17.8	29.5	25.1	37.8

4.4.3 $PM_{2.5}$ Inside/Outside Ratio

The minimal influence of the vehicle ventilation system settings on the pollutant concentrations inside the vehicles was discussed in section 4.2.1. It was noted, however, that the $PM_{2.5}$ integrated particle mass concentrations were significantly reduced inside compared to immediately outside each vehicle. A further review of the $PM_{2.5}$ data, provided quantitative estimates of the aparent particle penetration losses (reduced inside-to-outside ratio) and the resulting "insulating" effect on inside exposures. The mean inside/outside ratio of $PM_{2.5}$ for Vehicle 1 was computed to be 71% for the High vent setting and 59% for the Low setting. Although there is a suggestion of greater losses at the Low setting, the limited number of data points and the concentration variability provided no basis for a distinction between the vent settings. The composite ratios for the Ford Taurus and Ford Explorer (Vehicle 2) were similarly 64% for the High settings and 58 % for Low. Compositing the data for the three vehicles, suggests that an approximate 35 to 50 % reductions in $PM_{2.5}$ particle exposures during commuting is provided by the vehicle "envelope" with the windows closed. No data were collected on inside to outside PM_{10} ratio, but even lower penetration than $PM_{2.5}$ would be expected. Although various physical explanations were attempted to explain the significantly lower $PM_{2.5}$ levels inside the vehicle (e.g. vent system and interior wall losses, non-representative outdoor sampling location, occupant inhalation, etc.), insufficient information was available from which to form a definitive conclusion. The significance of this finding definitely merits additional study to corroborate the results and define the cause.

Although it would be assumed that opening the windows would provide relatively free flow between the inside and outside, no data were collected during the Main Study (except for the special school bus commutes) to support this surmise. The sedan air exchange measurement of 160 ACH @ 60 mph [2.7 air changes/minute] made during the Pilot Study with the windows only partly open (see Figure 3-6) showed substantial air exchange. Even though the bus traveled at slower speeds, its AER was expected to be substantial with the windows open.

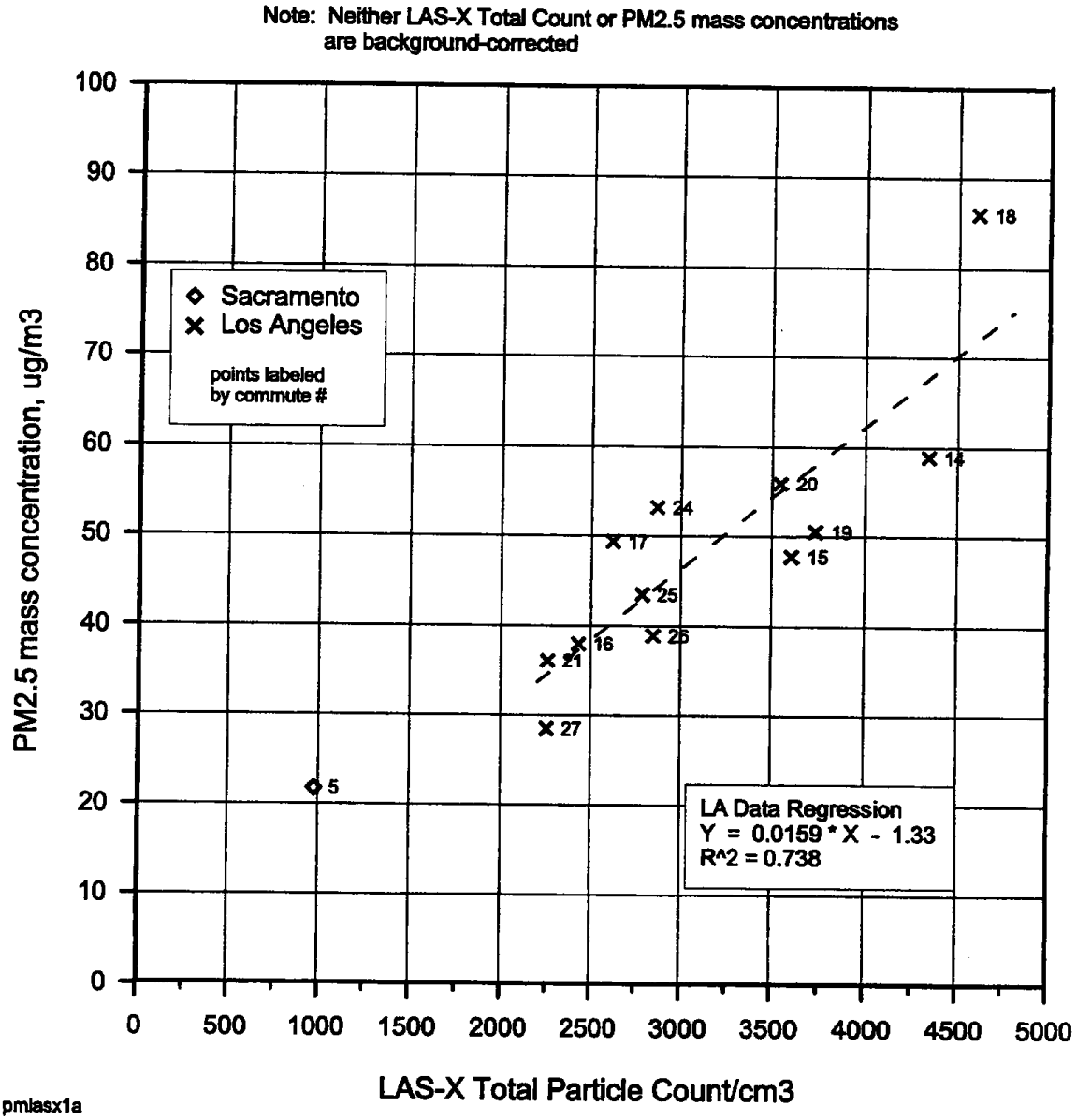
4.4.4 Relationships Among $PM_{2.5}$ Integrated Mass, LAS-X Count, and Black Carbon

Particle count concentration is computationally related to particle mass concentration by computing the total particle volume and applying a composite particle density. Fine particle sources influencing in-vehicle concentrations, especially poorly controlled diesel fuel combustion, may produce substantial numbers of fine particles that have only minimal impact on the integrated mass concentration. However, if the (a) the composite ambient density and (b) the particle size distribution are relatively constant, the empirical relationship between total count and mass may be roughly linear. Using only the LA data (since all but one of the non-special commute Sacramento $PM_{2.5}$ concentrations were <MDL), the ability of the LAS-X count to predict integrated $PM_{2.5}$ mass concentrations were assessed graphically (see Figure 4-18). The data indicate that most of the LA commutes, except # 18 fell approximately along a linear regression. The uncertainty in this relationship suggests that the greatest value of the LAS-X total count concentration data are as indicators of the presence of high emitting combustion sources, rather than as predictors of $PM_{2.5}$ mass.

The relationship between $PM_{2.5}$ integrated mass concentrations and black carbon for the non-special commute LA data is shown in Figure 4-19. The uncertainty in the relationship is similar to that of Figure 4-18. The slope of the regression suggests that carbon accounts for approximately 28

% of the $PM_{2.5}$ mass in in-vehicle settings. The relationship between LAS-X total particle count and black carbon, compositing both Sacramento and Los Angeles non-special commute data is shown in Figure 4-20. The uncertainty in the relationship is attributed to a number of factors including differences in ambient air concentration levels between Sacramento and LA, and differences from commute to commute in the influence of diesel emissions.

Figure 4-18. Relationship Between LAS-X Total Count In-Vehicle Concentration (0.15 to 2.5 um) and PM2.5 Concentration (excluding Special Study Commutes)



File: pmlasx1a

Figure 4-19. Relationship Between In-Vehicle PM2.5 Mass Concentration and Black Carbon Concentration (excluding Special Study Commutes)

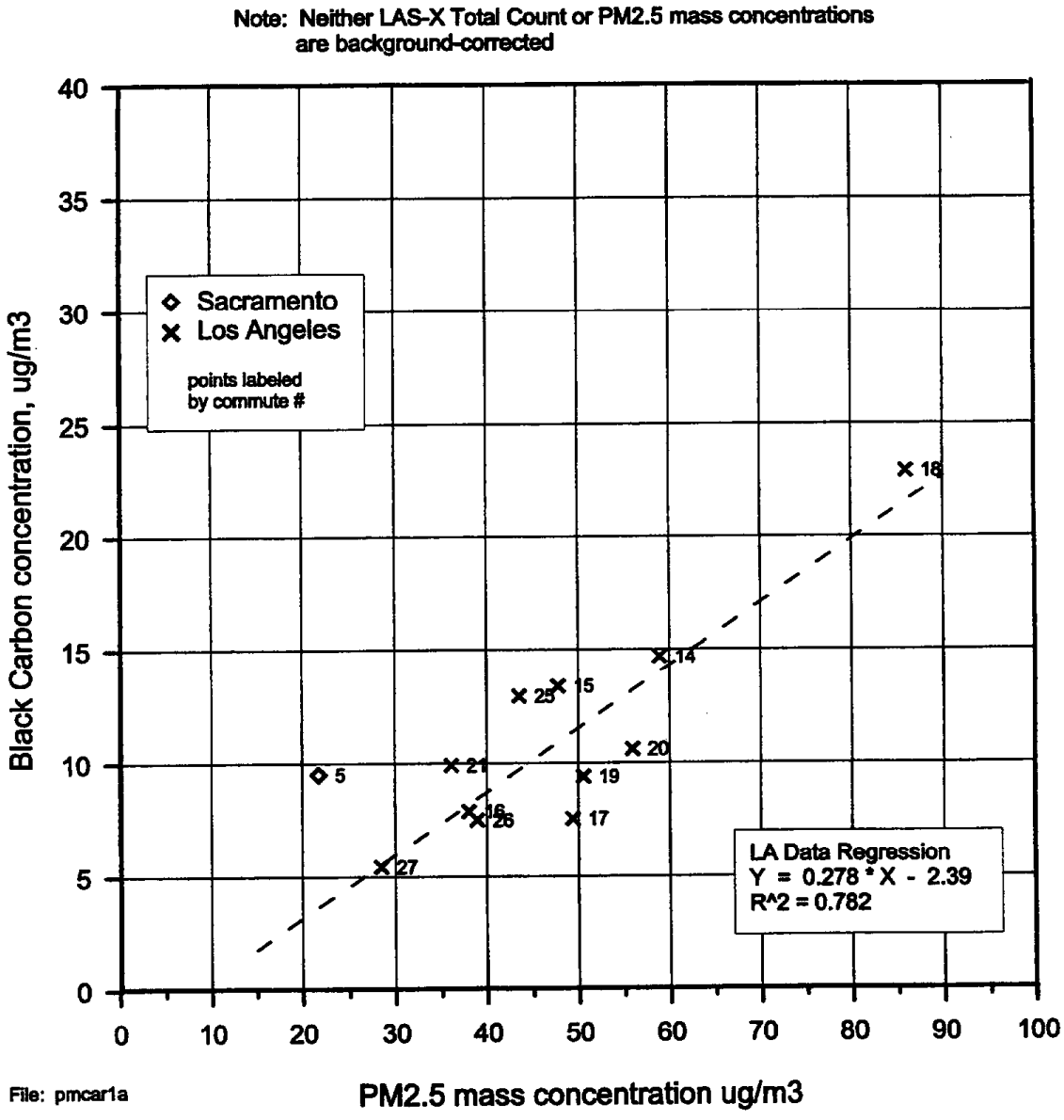
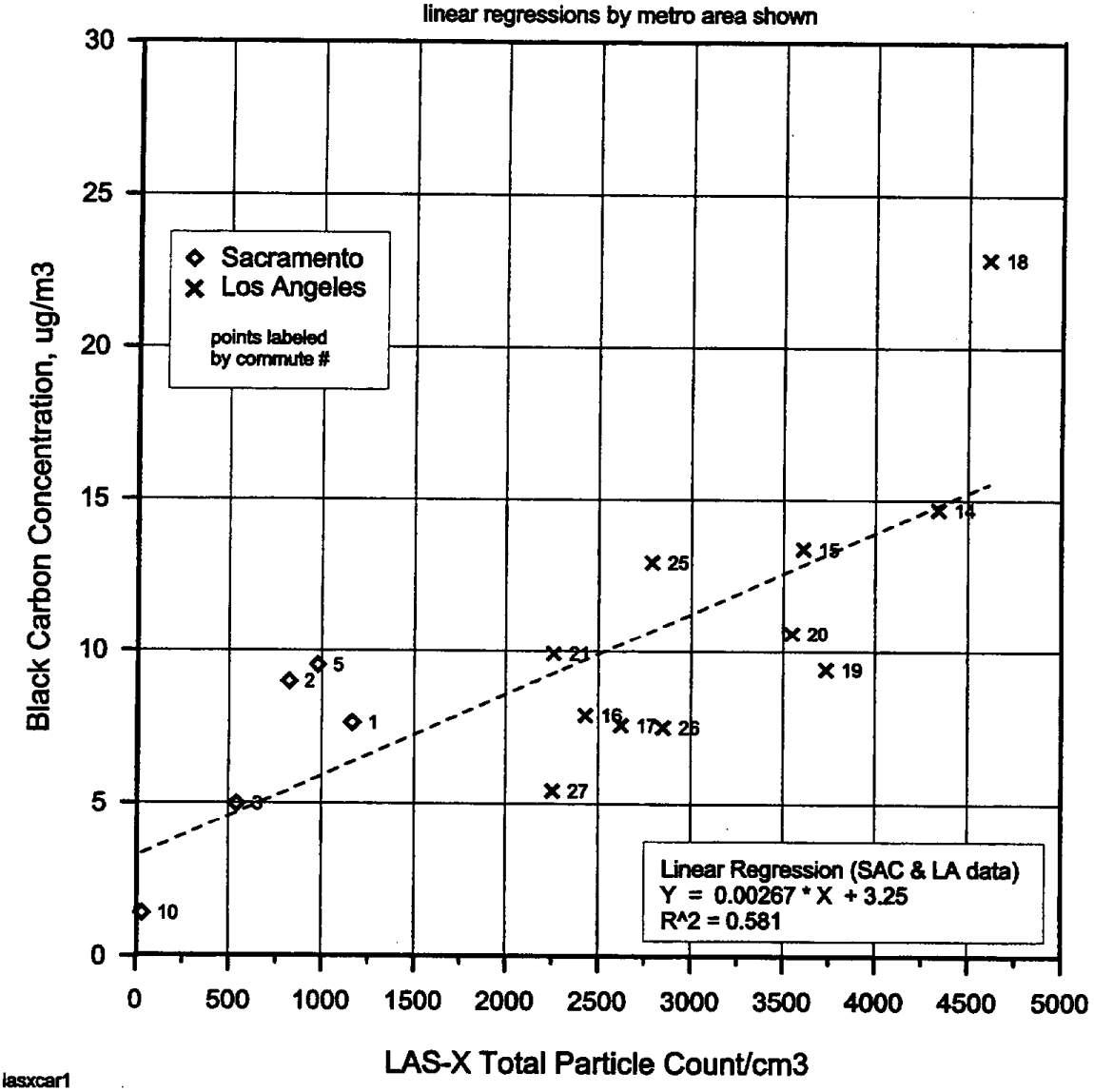


Figure 4-20. Relationship Between LAS-X Total Count In-Vehicle Concentration (0.15 to 2.5 um) and Black Carbon Concentration (Excludes Special Study Commutes)



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4.4.5 Relative Levels: Inside/Outside/Roadside/Ambient

The relative concentration levels of pollutants at the ambient and roadway sites, relative to the actual in-vehicle concentrations is important for predictive purposes. Properly selected ambient monitoring sites should provide a reasonable representation of the population's pollutant exposures for the scale represented by the fixed site. Since some pollutants are known to exhibit stronger spatial gradients than other (e.g. $PM_{2.5}$ is often much more uniformly distributed in a metropolitan area than is PM_{10}), the optional use of a roadway site to better indicate in-vehicle concentrations may be desirable.

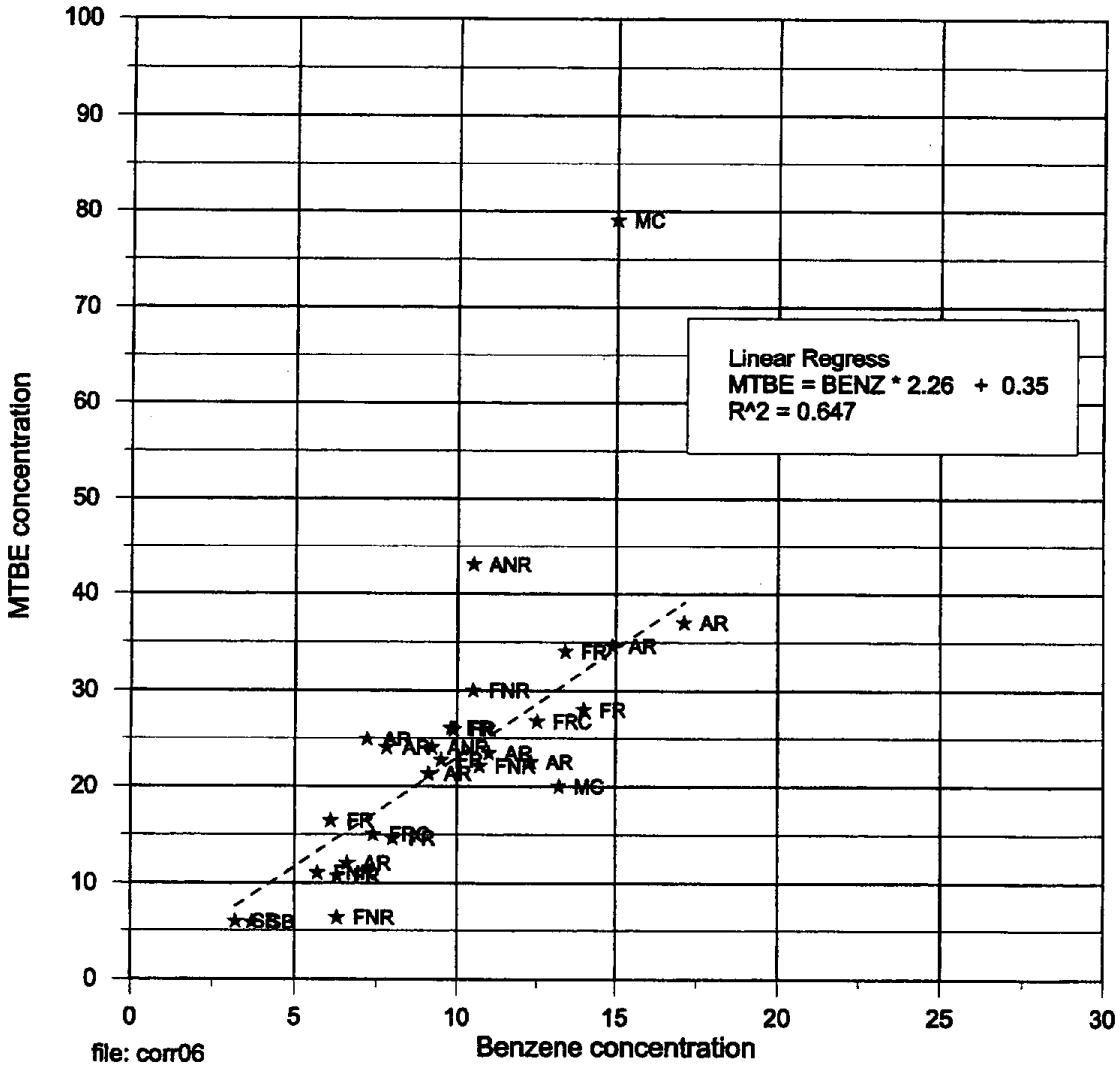
A review of the summary tables 3-4A thru F and 3-5A thru F for Sacramento and LA, provides relative indications of the ranges of individual pollutants measured at roadside and in-vehicle, relative to the measured ambient means for various commute scenarios. For MTBE, the ambient levels were typically 2 to 7 $\mu g/m^3$, while the roadway measurements were only slightly higher at 1 to 14 $\mu g/m^3$. The in-vehicle concentrations, however, ranged from 3 to well over 30 $\mu g/m^3$, suggesting that neither ambient or roadside locations provide estimates within a factor of 2 of the in-vehicle levels. The relatively consistent relationship between the ambient measurements and the in-vehicle MTBE levels (see Figure 3-2) suggests that predictive relationships based on the ambient data are viable. This is similarly true for the gasoline-related VOC's benzene, toluene, and the xylenes, as well as for formaldehyde. Factors such as the influence of the exhausts of single lead vehicles on in-vehicle exposures shown in section 4.4.1, suggests that a more robust data base would be required to actually construct reasonably accurate predictive models relating ambient to in-vehicle pollutant concentrations. Chan et. al. (1991) attempted to apply simple linear regression models to relate roadside and in-vehicle VOC concentrations and found relatively large intercepts and error terms. Similar to this study, they found that sites very close to the roadway, were required to provide even modestly accurately predictions of in-vehicle exposures.

A potentially useful ratio of in-vehicle MTBE/Benzene (see Figure 4-21) was found to be approximately 3. The actual California gasoline ratio for MTBE/Benzene is apparently nearer to 11. Presuming that the measured MTBE and benzene levels in Vehicle 1 were primarily from the exhaust (the vehicle fuel system was carefully checked for leaks), this suggests that these ratios may provide markers for MTBE exposures resulting from exhaust emissions, as compared to those from fuel vapor emissions.

Integrated in-vehicle particle measures were only modestly predictable by ambient and roadside sites, especially for $PM_{2.5}$. PM_{10} relationships are obviously confound by the contributions of intervening significant sources between the ambient, roadside, and in-vehicle measurement locations. The relatively consistent relationship shown in Figure 3-3 for $PM_{2.5}$ also suggests that predictions of in-vehicle levels based on ambient or roadside data are possible.

The very low concentrations measured at both the ambient and roadside sites were consistently below the MDL of the study monitors. This makes it impossible to draw conclusions about predictive relationships for CO.

Figure 4-21. ARB Main Study Raw Vehicle 1 Benzene Against Vehicle 1 MTBE



4.4.6 Concentration Comparisons with Other Studies and Data

This study focused on California driver exposures to pollutant concentrations in California settings. Only limited relevant data were found specific to concentrations of several of the target pollutants (especially MTBE and $PM_{2.5}$ mass) inside California vehicles commuting on California roadways. Shikiya et al. (1989) reported selected VOC's (canister collection), formaldehyde, and metals (undefined size cutpoint) collected during in-vehicle commutes in the Los Angeles area. Although this is probably the most relevant data base for comparison with the current results, significant differences in driving protocol, data stratification by commute type, and averaging time make simple comparisons difficult. Also, of the target analytes, neither MTBE or $PM_{2.5}$ mass (or metals) were reported.

As shown in Table 4-15, benzene and toluene ranges were consistent with the current study. The CO levels were significantly higher in the Shikiya data, probably due to differences in emission controls. Comparing PM_{10} metals showed similar chromium, nickel, and cadmium concentrations, but significantly lower lead levels in the current study by nearly an order of magnitude (note that all metal concentrations are significantly below the current study MDL's – see Table 3-3B). The latter Pb reduction undoubtedly resulting from the phase-out of leaded auto fuel.

Table 4-15 Selected Analyte Concentration Ranges Compared to Shikiya et al., 1989[8]

Analyte	Current Study Range	Shikiya et al., 1989
benzene, $\mu g/m^3$	12.7 – 17.2	13.3
toluene, $\mu g/m^3$	31.5 – 44.4	36.3
CO, ppm	3.5 – 5.1	8.6
PM_{10} Cr, $\mu g/m^3$	0.01 – 0.02	0.012
PM_{10} Ni, $\mu g/m^3$	0.01 – 0.02	0.009
PM_{10} Cd, $\mu g/m^3$	0.00 – 0.09	0.001
PM_{10} Pb, $\mu g/m^3$	0.00 – 0.02	0.218

Chan et al. (1991) reported in-vehicle VOC concentrations on highways in North Carolina, however, MTBE concentrations were not reported. Additionally, the significantly different fuel components and vehicle emission control systems in North Carolina and California, must be considered when comparing the current study with other less specific results. In-vehicle levels of benzene were reported by Chan et al. (1991) to range from ~1 to 43 $\mu g/m^3$, with a mean of 12. The mean ambient background benzene level was ~ 2 $\mu g/m^3$. The ratios of in-vehicle to ambient site VOC concentrations were reported to range from about 6 to 8. These data are reasonably consistent with the current study for Sacramento, but much higher than the ~3 to 5 ratio range in Los Angeles.

Sheldon et al. (1991) reported indoor, outdoor and personal VOC's for Woodland, CA, in June, 1990, and compared these results to previous California VOC studies. The Woodland outdoor benzene median concentration was reported to be 1.1 $\mu g/m^3$, with a personal median concentration of 3.1 $\mu g/m^3$. These benzene concentrations could be compared to the current study data showing a

[8] Current study in-vehicle (IN 1) data range across commute types from Table 3-5A; Shikiya et al., 1989 mean of all commutes from Table 3-1.

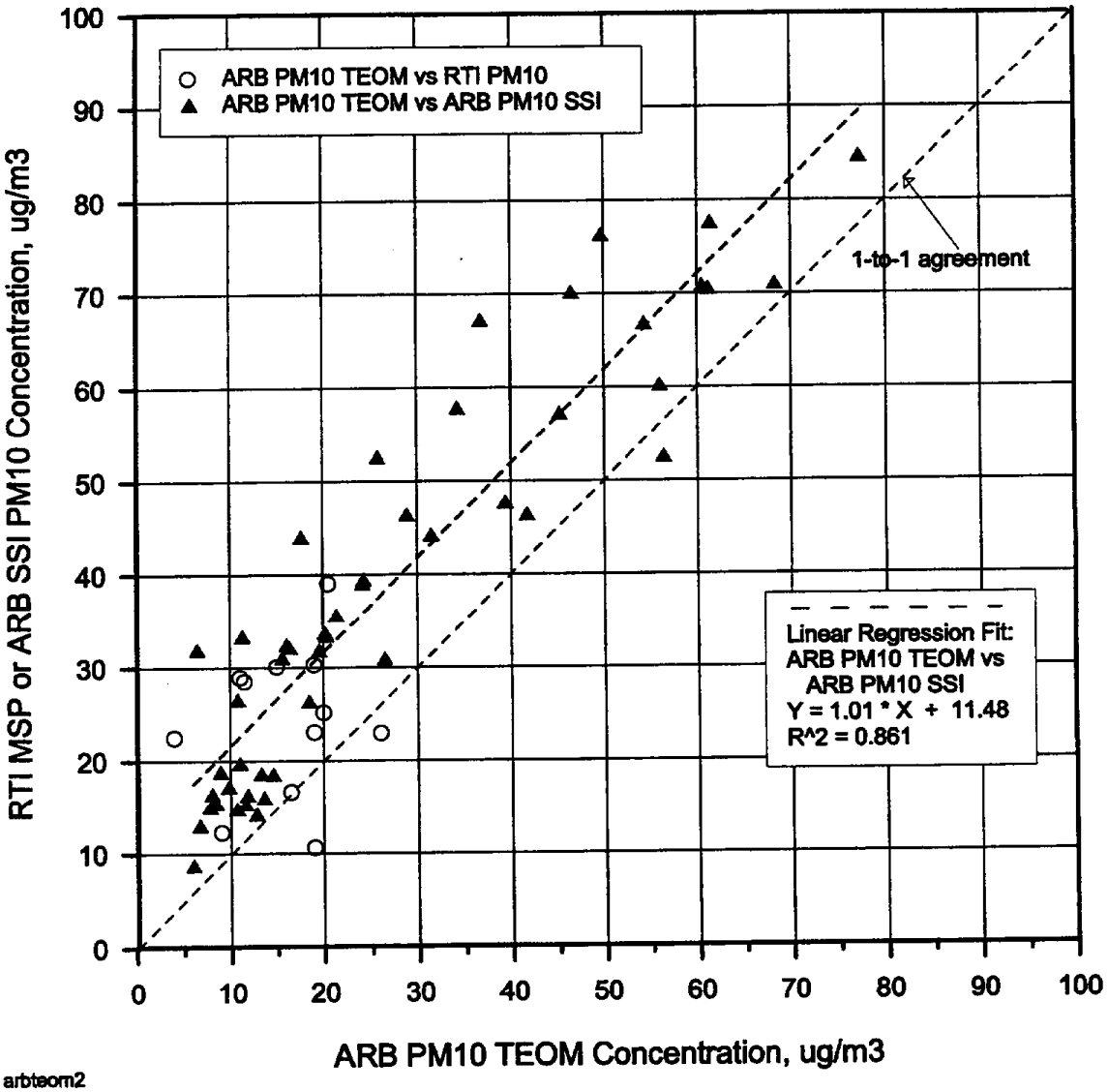
range of vehicular microenvironmental means in Sacramento of ~3 to 12 $\mu g/m^3$ and from ~13 to 17 $\mu g/m^3$ in Los Angeles. While some data were reported by Sheldon et al. (1991) inside automobiles, none of the measurable in-vehicle VOC's overlapped with the present study. Sheldon et al. (1995) reported benzene and carbon monoxide concentrations in Los Angeles elementary schools in 1991 and 1992. The study surprisingly showed median benzene levels ranging from 3.8 to 15 $\mu g/m^3$, which are consistent with the in-vehicle levels of the present study, without the direct influence of a vehicular microenvironment. The corresponding median CO concentrations in the schools reported by Sheldon et al. (1995) ranged from 0.6 to 6.6 ppm, also similar to the in-vehicle CO levels of the present study.

The PTEAM study (Pellizzari et. al, 1992) provided daytime mean 12 hour $PM_{2.5}$ concentrations in Riverside, CA, of 35 $\mu g/m^3$, with a mean $PM_{2.5}$ /PM_{10} ratio of 0.49. These data were from a fixed-site that had no influences from nearby localized sources. The concentration mean is reasonably consistent with the ambient data from the Main Study, considering the influences of spatial and seasonal factors. The mean Main Study $PM_{2.5}$ /PM_{10} ratio of 0.58 for LA is only slightly higher than the PTEAM result. No in-vehicle $PM_{2.5}$ concentration data for California were found against which the current study data can be compared.

The continuous black carbon data from the Aethalometer in Figure 4-9, suggests that a typical freeway rush in-vehicle concentration when not behind a "target" vehicle was in the 5 to 10 $\mu g/m^3$ range. Figures 4-9, 4-10, and 4-12 suggest that following a HDD "target" elevates this level to the 40 to 100 $\mu g/m^3$ range. These findings can be compared with the data of Hansen and Novakov (1990), who reported that elemental carbon levels 50 meters from a diesel bus plume were elevated ~5 $\mu g/m^3$ above the background level. Gray et al. (1984) reported a mean elemental carbon level of ~5 $\mu g/m^3$ in Southern California. The freeway trailing distances during the Main Study averaged ~50 feet (~16 m) during freeway commutes, these distances were typically only half that during heavy congestion. This undoubtedly could raise the in-vehicle concentrations substantially.

The available ARB data from the ambient sites in Sacramento and Los Angeles were typically over much longer measurement periods and could not be compared directly for most pollutants. Hourly data from an ARB PM_{10} TEOM sampler at the Sacramento ambient site provided the limited comparison data shown in Figure 4-22. Consistent with the findings of others, relative to the TEOM, the study PM_{10} concentrations are consistently higher by approximately 5 to 15 $\mu g/m^3$. This could be the result of short term particle volatilizations from the heated TEOM substrate. A brief review of the ambient CO data in Los Angeles at the Pico Rivera site during the Main Study commutes, showed higher AM than PM levels, consistent with the decrease found in this study with wind speed for CO (and MTBE). The ARB mean ambient CO levels at the Pico Rivera site were <2 ppm for both AM and PM, supporting the (<MQL) study findings.

Figure 4-22. Relationship Between ARB Ambient Site PM10 (TEOM) and RTI Ambient Site PM10 (MSP inlets) for 2 Hour Samples Collected During Sacramento Main Study (9/8 - 9/15/97)



File: arbteom2

5.0 Summary and Conclusions

5.1 General

An in-vehicle air monitoring study for particles and a variety of organic and inorganic chemicals was conducted in Sacramento and Los Angeles, using vehicles complying with California emission requirements. The study was "successful" in terms of meeting the data quality and data capture goals, as well as addressing the defining study hypotheses. This "Main Study" followed a Pilot Study conducted previously (2/97) that validated the measurement methodologies needed to collect data of acceptable quality, during relatively short commute sampling periods (2 hours). The value of the Pilot Study in producing robust measurement methodologies was fully realized in the exceptionally high data capture rates (for such a complex Main Study) and the excellent data quality. The data quality objectives were met for all pollutant measures, except the particle metals, given the limited ability of the XRF analyses to provide robust quantitation for the target analytes.

A wide range of pollutants were studied, including a suite of VOC's, formaldehyde, $PM_{2.5}$ and PM_{10} particle mass and elemental composition, plus real-time CO, black carbon, and particle count by size. Vehicular commute characteristics were also successfully recorded, including speed, lead vehicle trailing distance, Level of Congestion, and the fraction of leading vehicles that were diesel. A continuous video record subsequently permitted associating the type of lead vehicle with selected in-vehicle concentrations for five LA commutes, using the real-time pollutant measures.

The balanced factorial study design represented a variety of routine commuting scenarios on freeway and arterial roadways, during rush and non-rush hour periods, during both AM and PM time windows, and for several vehicle types, including two different sedans and a sport-utility vehicle. Thirteen commutes were driven in Sacramento in early September, 1997, while 16 additional commutes were subsequently driven in Los Angeles in late September and early October, 1997. Only two duplicates were conducted for each scenario, providing a somewhat limited data base from which to conduct statistical analyses. Commuting routes were selected that were reasonably typical of the most frequently traveled scenarios, and included a comparison of freeway carpool and non-carpool lane commutes. A driving protocol was also defined that highlighted trailing behind heavy duty diesel (HDD) vehicles and diesel city buses when possible, to estimate their contributions to selected pollutants. This focus on trailing specific polluting vehicles provided "high-end" estimates of the in-vehicle concentrations, especially for particle mass and black carbon. The ease of following these "target" vehicle types during non-rush commutes, may have significantly affected the representativeness of these concentrations to represent the non-rush scenarios. Several special studies were conducted, including measuring concentrations inside a commuting California school bus in Sacramento, inside a sedan commuting in a Los Angeles carpool lane, and in a sedan intentionally focusing on situations that may provide maximum vehicular concentrations.

The continuous measurement of particle count by size using a calibrated LAS-X optical particle counter, and black carbon using an Aethalometer, worked well on the mobile sampling platform inside the primary sedan. The primary problem during the commutes was the erratic operation of the on-board AC power system for these two monitors. Unexpected power failures were encountered that interrupted the data collection computer and software on several commutes. The application of an alternating sampling scheme (1 minute inside, 1 minute outside) permitted one continuous monitor of each type to be used for both measurement locations.

5.2 Specific Summary Highlights

In order to provide the clearest summary of salient study highlights, a bulleted format is used.

Methodology

- Data capture rates were excellent for all pollutant measures, especially when the difficulties associated with sampling in a mobile environment are considered.
- Following a selected "target" vehicle for any extended periods was least likely to occur during congested freeway rush commutes, suggesting that these commutes probably produced the most representative concentration levels.
- While VOC commuting concentrations were well within the analytical sensitivity range, most of the pollutant measures were near their measurement quantification limits in many cases, due partly to the very short sampling period, and also to low concentrations in some scenarios.
- The VOC canister sampling methodology provided excellent data quality,
- $PM_{2.5}$ and PM_{10} gravimetrically-determined concentrations were successfully determined, even though the samples were integrated over very short 2 hour periods at only 4 lpm (0.48 m^3).
- The relatively low levels of CO currently found in commuting California vehicles, posed a significant measurement problem for portable monitors with an MQL of 2 ppm.
- The DNPH tube formaldehyde collections provided consistent data quality, but were limited to in-vehicle collections only. The LA sample collections was supported by SCAQMD.
- Continuous monitoring of in-vehicle CO concentrations could be readily associated with emissions from older, poorly tuned gasoline-powered vehicles just ahead of the study vehicles.
- Continuous monitoring of in-vehicle particle count and black carbon concentration can be readily associated with emission of diesel-powered and poorly tuned gasoline-powered vehicles just ahead of the study vehicles.
- The additional LA work, supported by SCAQMD, added significantly to the understanding of factors influencing in-vehicle concentration levels - especially the influence of leading diesel vehicles.
- The use of an outside sampling tube for collecting particles was shown to result in particle losses during transit of 10 to 25%, depending on the particle size. The estimated influence of the outside sampling line on $PM_{2.5}$ mass concentration was ~19 to 21 %.

Pollutant Measures

- Most pollutant levels were elevated inside and outside the vehicles, relative to either the roadside or ambient concentrations.
- Most pollutant levels were extremely low at the rural site, relative to any of the vehicular or roadway locations.
- Most pollutant levels were at least somewhat higher in Los Angeles than in Sacramento, undoubtedly due in part to the larger base of vehicular emissions.
- Particle concentrations were typically significantly higher outside - attributed to losses in the vehicle ventilation systems, while insignificant differences were observed between inside and outside of the same vehicle for gas phase pollutants.

- Inside vehicle pollutant concentrations for some individual commutes were substantially influenced by the tailpipe emissions from single polluting "target" lead vehicles.
- An estimate of the relationship between vehicle spacing (to a polluting "target" vehicle) and the in-vehicle concentration level, could not be reasonably quantified from the study data. While it was clear that concentrations generally diminished with increasing trailing distance, too many uncontrolled variable (e.g. exhaust location, adjacent lane exhausts, emission rate changes during acceleration, etc.) confounded simple efforts.
- The difficulty in following a selected "target" vehicle was least likely to occur for an extended period during freeway rush commutes, suggesting that these commutes are produced the most representative concentration levels.
- The approximate in-vehicle study pollutant concentration ranges (not ambient corrected) by city are provided in Table 5-1.

Table 5-1. Summary of Approximate In-Vehicle Pollutant Concentration Mean Ranges in Sacramento and Los Angeles

NOTE: Concentrations are not ambient corrected

Pollutant	Sacramento Ranges	Los Angeles Ranges
Isobutylene, $\mu g/m^3$	3 to 14	12 to 25
1,3-Butadyiene, $\mu g/m^3$	1 to 4	2 to 6
Acetonitrile, $\mu g/m^3$	18 to 345	6 to 375
TCFM, $\mu g/m^3$	<MQL	<MQL
DCM, $\mu g/m^3$	1 to 4	1 to 5
MTBE, $\mu g/m^3$	3 to 36	20 to 90
ETBE, $\mu g/m^3$	0 to <1	0 to <1
Benzene, $\mu g/m^3$	3 to 15	10 to 22
Toluene, $\mu g/m^3$	7 to 46	22 to 54
Ethylbenzene, $\mu g/m^3$	2 to 10	5 to 12
m,p-Xylene, $\mu g/m^3$	5 to 38	18 to 45
o-xylene, $\mu g/m^3$	2 to 13	6 to 16
PM10, $\mu g/m^3$	20 to 40	35 to 105
PM2.5, $\mu g/m^3$	6 to 22	29 to 107
Formaldehyde, $\mu g/m^3$	5 to 14	0 to 22
CO Mean, ppm	0 to 3	3 to 6
PM2.5 Sulfur, $\mu g/m^3$	0.1 to 0.9	0.7 to 3.9
Black Carbon, $\mu g/m^3$	0 to 10	3 to 40
LAS-X, particles/cm3	10 to 1,100	2,200 to 4,600

Notes: means of 2 to 4 commutes; <MQL – no quantifiable data

- Of the non-target particle elements, only Fe, K, Na, Si, Cu, and P were routinely elevated above the MQL for $PM_{2.5}$ for Sacramento or LA. For PM_{10}, Na, Mg, Al, Si, P, K, Ca, Fe, Cu,

and Zn were frequently elevated above the MQL.

- Total LAS-X particle count (0.15 to 2.5 μm) was a fair predictor ($R^2 = 0.74$) of integrated $PM_{2.5}$ mass concentration.
- Both total LAS-X particle count and black carbon appeared to be excellent indicators of the influence of diesel vehicle exhaust on in-vehicle concentrations.
- Black carbon comprised approximately 28 % of the in-vehicle $PM_{2.5}$ integrated mass during the Los Angeles commutes.
- The ambient backgrounds were subtracted from the in-vehicle concentrations for most pollutants to estimate the vehicular microenvironmental contributions during specific commuting scenarios. For freeway rush commutes, the ranges of approximate incremental contribution for three selected pollutants were:

  MTBE: 18 to 20 $\mu g/m^3$ in Sacramento, and 23 to 24 $\mu g/m^3$ in LA

  $PM_{2.5}$: 1 to 9 $\mu g/m^3$ in Sacramento, and 0 to 12 $\mu g/m^3$ in LA

  Carbon Monoxide: 2.1 to 3.1 ppm in Sacramento, and 4.6 to 4.9 ppm in LA

Vehicular Measures

- The mean vehicular speed for freeway commutes was 33 mph in Sacramento, and 42 mph in LA.
- The mean commute miles traveled (in 2 hrs) on the freeway was 68 miles in Sacramento, and 84 miles in LA.
- The mean vehicular spacing for freeway commutes was 69 feet in Sacramento, and 50 feet in LA.
- The approximate vehicle air exchange rates ranged from 6 to 98 ACH for 3 different vehicles over the speed range from 35 to 55 mph.
- The constant speed air exchange rate of a 1997 Ford explorer was found to range from 2 ACH for 0 mph and a low vent setting to 56 ACH for 55 mph and a medium vent setting.

5.3 Conclusions/Recommendations

One of the most significant results of this effort was the development of the methodologies to address hypotheses regarding in-vehicle concentrations, during both the Pilot Study and the Main Study portions of the field sampling. The in-vehicle sampling during simulated 2 hour commutes in California settings, using both continuous and integrated measurement methods, provided robust data bases for both gas and particle species. These measures included those integrated over the 2 hour period - VOC's, particle mass (including $PM_{2.5}$), formaldehyde, and three continuous measurements - CO, black carbon, and particle count <2.5 μm.

The influences of specific variables on in-vehicle concentrations were assessed by utilizing a balanced factorial design that defined specific driving scenarios and locations. The variables studied included the influences of: (a) vehicle type, (b) vehicle ventilation settings, (c) roadway type (freeway vs arterial), (d) level of freeway congestion (rush vs non-rush), and (e) time of day (AM vs PM). These variables were studied in two locations, Sacramento, CA and Los Angeles, CA. The limited amount of data collected for each scenario (maximum of 4 commutes per scenario) and the driving protocol focusing on a specific target vehicle type (heavy duty diesels), however, significantly limited the ability to address these influences statistically. Comparisons of composited scenario means were evaluated to study each influence variable and subjective observations drawn. These observations suggested the following conclusions regarding the specific study objectives.

- The influence of vehicle types (1991 Chevrolet Caprice, 1997 Ford Taurus, and 1997 Ford Explorer) on in-vehicle concentration levels was determined to be minimal, due possibly to the rapid air exchange rates that occurred with all vehicles tested at typical commuting speeds. Although significant differences between air exchange rates for each vehicle type may exist at low speeds (influenceing in-vehicle concentrations), the absence of low speed conditions during the field testing prevented this assessment.

- The influence of ventilation settings on in-vehicle concentration levels was determined to be minimal, also due possibly to the rapid air exchange rates that occurred at all vent settings tested.

- The influence of roadway types (freeway, arterial, rural) on in-vehicle concentration levels was very significant for selected pollutants for both Sacramento and LA, but was found to be variable and complex. The substantial influence of single (polluting) lead vehicles – which are present on all roadway types - on in-vehicle concentration levels appears to be an important confounding factor. Another important factor (not directly addressed experimentally) that is related to roadway type, appears to be the trailing distance to the lead vehicle, often dictated by the traffic density.

- The influence of freeway congestion level (rush, non-rush) was also found to be complex, but appeared to be most significantly influenced by the associated parameter of spacing distance to the leading vehicle. The limited (and variable) data set made it difficult to provide a definitive conclusion. In general, the Freeway Rush commutes did appear to show significantly higher background-corrected in-vehicle concentrations than did the Non-Rush commutes.

- The influence of time-of-day (AM or PM) was also found to be complex, and primarily a function of setting (Sacramento or LA), Level of Congestion, and the local meteorology. While Sacramento had a significantly higher PM Level of Congestion (and associated in-vehicle concentrations), LA concentration data appeared to be most significantly influenced by the AM to PM change (a substantial wind speed increase) in local meteorology.

In general, the vehicle-specific influences (vehicle type and vehicle vent setting) appeared to be minimal factors (especially relative to other variables) affecting in-vehicle concentrations under the conditions tested. The remaining categorical factors (roadway type, freeway congestion level, and time-of-day) had variable influences, most often controlled by more specific underlying factors, including: (a) the experimental driving protocol (trailing specific polluting target vehicles), (b) the often pronounced influence of emissions from the lead vehicle, (c) spacing to the lead vehicle, and (d) the local meteorology (wind speed). The combination of the limited number of commutes (max of four for each influence category, and a study design that did not specifically address these underlying variables, makes it difficult to draw more substantial conclusions.

Salient Additional Conclusions:

Some of the additional findings of this study may prove to be of greater value than those addressed by the original study objectives, including:

- The role of single polluting vehicles immediately in front of the test vehicles was substantial, even for short periods, occasionally accounting for 30 to 50 % of the total in-vehicle commute exposure.
- "Target" Ethanol or CNG-fueled city buses provided in-vehicle total particle count levels than were 3 to 5 times lower than diesel buses, and black carbon in-vehicle concentrations that were 60 to 80 $\mu g/m^3$ less.
- "Target" older gasoline-powered sedans were most consistently the cause of elevated in-vehicle CO levels, especially at stoplights.
- The ventilation systems of the test vehicles (with the windows closed) significantly reduced the penetration of particle mass <2.5 μm by 20 to 40 %.
- Passenger exposures inside a California school bus was quite low, reflecting the generally lower concentrations in residential neighborhoods, compared to settings with more vehicular influences.
- Carpool lane commutes substantially reduced in-vehicle pollutant concentrations by 30 to 60 %, and additionally reduced total commute exposures by reducing total commuting time.
- Maximum concentration situations during commutes (e.g. closely trailing a diesel city bus in a street canyon) could readily double the short-term in-vehicle concentrations for selected pollutants.
- Roadside pollutant measurements provided significantly better indications of in-vehicle pollutant concentrations than did ambient sites, but were still low by factors of 2 or more many commuting scenarios.
- Correcting the in-vehicle concentrations by subtracting the ambient background levels,

provided a more robust method of assessing the contribution of the commuting microenvironment to total air exposure.

Salient Recommendations:

Specific recommendations related to in-vehicle concentration measurement studies include:

- VOC's by canister collection and GC/MS analysis methodologies can readily be used for 2 hour commute averages, as can DNPH formaldehyde collections with HPLC analysis.
- Extraordinary care must be taken to obtain reliable gravimetric $PM_{2.5}$ and PM_{10} concentrations over such short durations (and low flowrates) – but are possible. The design of future particle exposures studies over such limited integration intervals, should consider longer periods to improve the MQL's.
- An outside sample line should only be used (to compare inside/outside particle ratios), if some means (similar to the size distribution comparison conducted here) is available for estimating particle losses.
- Refinements and improvements are needed for real-time particle samplers, which are still too bulky to use easily in private automobiles without unduly altering the normal environment and/or the activities of the occupants.
- The integrated sampling methodologies for NO_2 and PAH's need to be improved to collect measureable, short-term (2-hour) samples inside commuting vehicles.
- Continuous in-vehicle particle counting is only recommended for future studies if the device has been specifically calibrated for the type of aerosol to be encountered.
- Continuous black carbon measurements using the Aethalometer were very easy to make experimentally, but should be compared in future studies with limited integrated collections on quartz substrates and thermal decomposition analysis methodology to verify the measurement accuracy.
- The relationship between trailing distance and in-vehicle concentration should be investigated to provide better guidance on the potential mitigating influences of following less closely.
- Further quantification of the advantages of carpool commuting relative to pollutant exposures should be considered.
- Further measurements and/or modeling are suggested to estimate the relative contributions of ambient versus vehicular pollutants in the commuting microenvironment.
- Further work is suggested evaluating the relative importance of single lead vehicles on in-vehicle exposures, especially in terms of the relationship of the emission rates of older (compared to newer, better-controlled) vehicles to in-vehicle exposures.
- Further work is suggested on the potential impact of individual poorly-tuned (or maintained) diesel vehicles on black carbon and particle mass in-vehicle concentrations.
- The potential for high concentrations of fine particle levels during rain events should be investigated to determine if the phenomenon is reproducible and the mechanisms by which in-vehicle particle concentrations are being elevated.

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7.0 Glossary

Salient abbreviations, acronyms and words peculiar to this report are identified as follows:

Organizations
AD - Aerosol Dynamics, Inc.
ARB - Air Resources Board of the California Environmental Protection Agency
DRI - Desert Research Institute
EPA - Environmental Protection Agency
RTI - Research Triangle Institute
SCAQMD - South Coast Air Quality Management District
SR - Sierra Research, Inc.

Units
$\mu g/m^3$ - micrograms of pollutant per cubic meter of sampled air
ppm - parts per million of pollutant by volume
AER - Air Exchange Rate
ACH - Air Changes per Hour
LAS-X - particle counter model identification manufactured by Particle Measurement Systems, Inc.

Pollutant Acronyms
DCM - dichloromethane
ETBE - ethyl-tertiary-butyl ether
MTBE - methyl-tertiary-butyl-ether
PM_{10} - EPA designation for particles nominally <10 μm in aerodynamic diameter
$PM_{2.5}$ - EPA designation for particles nominally <2.5 μm in aerodynamic diameter
TCFM - trichloro-fluoro-methane
VOC - Volatile Organic Compound

Study Scenario Abbreviations
AMB - ambient site
ANR - Arterial Non-Rush
AR - Arterial Rush
FNR - Freeway Non-Rush
FR - Freeway Rush
FRC - Freeway Rush Carpool
IN 1 - inside vehicle 1
IN 2 - inside vehicle 2
LA - Los Angeles
SB - School Buss commute
MC - Maximum Commute
OUT 1 - outside vehicle 1
OUT 2 - outside vehicle 2

R - Rural
ROAD 1 - roadside site 1
ROAD 2 - roadside site 2
SAC - Sacramento
SUV - sport utility vehicle
Vehicle 1 - lead test vehicle, additionally outfitted with continuous monitors and vehicular measures
Vehicle 2 - test vehicle following Vehicle 1, or in an adjacent lane

Measurement Abbreviations

HPLC - high pressure liquid chromatography
GC/MS - gas chromatography followed by mass spectrometry (VOC analysis)
SUMMA - VOC canister surface passivation type
XRF - x-ray fluorescence (elemental analysis)

Miscellaneous

"Target" Pollutant - pollutant selected to be specifically measured, even though others in the class are reported (e.g. MTBE as a target for VOC's, formaldehyde, as a target aldehyde)
"Target" Vehicle - the vehicle immediate in front of the study vehicle, selected to follow by the driver
Level of Congestion – designation describing six subjectively-judged traffic density categories, ranging from 1 (extremely light) to 6 (extremely heavy).
HDD - heavy duty diesel
HSC - Health and Safety Code of the state of California
MDL - minimum detection limit
MQL - minimum quantification limit (3 times the MDL, if the MDL is defined)
PEM - personal exposure monitor